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RIVER CANAL CENTER FEASIBILITY STUDY AND MASTER PLAN

WINDSOR LOCKS CANAL HERITAGE STATE PARK

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I. INTRODUCTION

A. Major Findings and Historical Developments

This report documents a wide range of topics and resources which could be developed for interpretative themes of the Historic Exhibition Center and associated boat ride proposed at the Windsor Locks Canal State Park. Our research included use of documentary and informant sources, review of available images and artifacts, and personal inspection of many sites associated with the park area. The canal was originally known as the Enfield Canal when completed in 1829, and was gradually given the alternative name Windsor Locks Canal by the late 19th century; we use both names as appropriate.

We find that the canal is a direct outgrowth of the immediate river environment, the larger context of which must be understood for optimal interpretation. To focus better on thematic issues in phases II and III of the Feasibility Study and Master Plan (Market Analysis/Economic Feasibility, and Spatial Requirements/ Exhibit Concepts), we have chosen a topical or thematic presentation rather than a single chronological overview. This approach requires occasional redundancies among different report sections. Section I.B includes a brief chronological sketch of the principal historical patterns common to all topics. Since both natural and historical environments are closely related in the proposed park area, however, it is important to recognize the following linkages and developments which bind the topics together:

1. Enfield Rapids are the center of a unique and dramatic landscape along the Connecticut River, including fast river water below a calm canal, high banks and red rocks not seen elsewhere on the river in Connecticut, the largest entirely-waterbound island in the river, and important seasonal wildlife like shad and eagles.

2. The rapids created a set of obstacles and opportunities for people which strongly influenced cultural development. The principal obstacle was a barrier to river travel, especially upriver. The opportunities included anadromous fish capture (by Native Americans and Euroamericans), sites for fords, ferries, and bridges, and hydropower potential. The ford near the south end of the rapids is probably the only one on the river in Connecticut.

3. As a travel barrier, the rapids after 1635 became a major point within a complex regional trade network during a 250-year period. Avoiding the rapids led to the development of Warehouse Point opposite Windsor Locks as a transhipment point, and later to the construction of the canal. All major transportation components of the regional economy passed over or around the rapids, including canoes, sloops, rafts, flatboats, and steamboats.

4. The ambitions, failures, and successes of the Connecticut River Company (1824-1926) were critical to the growth of Windsor Locks as well as the development of the canal. This company began with the broadest schemes ever attempted on the river for control of transportation with a series of canals and fleets of steamboats, plus development of hydropower as a somewhat secondary concern. The growth of water-powered industry along the canal after the

navigation schemes failed (beginning c1845) created the industrialized town of Windsor Locks and much of the surviving urban-industrial environment.

5. The planning and construction of the canal (1824-29), with multiple schemes for working with the geographic setting and a spectacular 3-mile embankment built directly on the riverbed, became probably the most expensive contemporary canal built in the U.S., per mile.

6. Local industries along the canal included a high concentration of specialty manufacturers, some of whom captured or developed markets in unusual products with the potential interpretative appeal of striking textures/colors (e.g., colored tissue and filter paper, novelty yarns and fabrics, military braid) and astonishingly common applications (e.g., teabags, telephone cords, universal chucks).

7. After the Civil War, there were many new, ambitious schemes to navigate over the rapids, and to tap the full potential of the river's water power which the small canal could never begin to use. None of these schemes ever succeeded, but the plans show constant grappling with the power and potential of the river, and the failures show a stalemate of regional interests developed around and along the river. During this period, the canal and its owners were a hindrance to navigation, since they opposed anything that might inhibit their use of the water for power via the small canal.

B. Summary of Park Area Prehistoric and Historic Cultural Development

1. Native Americans

The freshwater, fish, and game resources of stream and river attracted prehistoric Indian peoples to the Enfield Rapids area, although we know very little of their settlement patterns or land use. Poorly-documented archaeological finds, some of which date to at least 5000 years ago, indicate probable hunting and fishing camps of pre-agricultural groups near the river and on King's Island. The importance of the rapids, with their seasonal fish runs, to these populations is suggested by numerous cremation and interment burials found along the Windsor Locks floodplain and adjacent areas of northeast Windsor. Some of these were associated with prehistoric artifacts (personal communications, Nicholas Bellantoni).

In the early 17th century, there was a substantial population of Native Americans in the Connecticut River Valley. The Algonquian-speaking peoples who lived there had practiced agriculture for 500-700 years, but they also continued to hunt, gather, and fish to supplement the crops from their fields. The falls at Windsor Locks would have been an obvious location for seasonal fishing camps, and there were probably villages with cultivated fields in the nearby area as well. Smaller bands hunted in this area in the fall and winter. The earliest white explorer, Adriaen Block, saw an Indian fort along the river above Hartford in 1614.

The European explorers and colonists, confused about the organization of and identification of various tribes and bands, have left us with many conflicting accounts of tribal names and leadership. Historians, responding to this confusion, have often referred to the many groups on the Connecticut River as the River Tribes. From early sources we see references to the Tunxis who lived to the west on the Farmington River, the Poquonocks at Windsor, the Massacos above the Poquonocks near Simsbury, and the Sicaogs in West Hartford. The territory of the Agawam, centered at Springfield, extended as far south as Stony Brook in Suffield. One authority has estimated the pre-epidemic population of these five "sachemdoms" at 3200 (Cook 1976: 57, 61-65). There were also Mattabesecs, Wongunks, and Hammonassets south of Hartford. The Podunks occupied lands on the east side of the Connecticut river opposite Hartford, ancient Windsor, and Suffield. In Enfield, a historic fort, probably used by the Podunks, has been informally excavated near the Scantic River east of Raffia Road (Bridge 1977). Larger tribes such as the Niantics, Pequots, and Mohegans lived along the southern coast and in interior areas south and east of Hartford (Cook 1976: 61-66: DeForest 1964: 51-55).

Disease, particularly the smallpox epidemic of 1633 and 1634 (apparently spread by contact with infected Dutchmen), devastated the native populations of this region. William Bradford reported that the Indians living near the Plymouth colony trading house at what is now Windsor "fell sick of the small pox and died most miserably.... very few of them escaped (Bradford 1967: 240.)" Pine Meadow, as much of Windsor Locks was known to early colonists, was apparently largely depopulated by the mid-1630s. Weakened by diseases, the surviving Indians gave away or sold most of the land in this region by c1637 (Stiles 1892,I: 104-11). Some contact period artifacts (copper beads) were found in 1871 with an Indian burial in Windsor Locks, attesting to the fact that Indians must have been there not long before European settlement commenced (Hayden 1900: 91-92).

Intertribal conflicts grew more violent and probably more frequent as Indians became dependent on European trade goods, involved in wider patterns of intertribal trade, and more involved with colonial governments. This was a region that saw considerable violence during King Philip's War in 1675-1676. Many of the Connecticut Indians fought with English colonists against other Algonquians in that war (Malone 1991).

2. Euroamerican Development

Most of the topics summarized here are treated in more detail elsewhere in this report. This discussion is intended only to provide a brief framework of local historical events and geography as general context for sections III-IX.

The Connecticut River was always an important travel corridor for early European settlers. Dutch explorer Adrien Block sailed upriver to the bottom of Enfield Rapids in 1614, the first serious obstacle for small sailing vessels, but no serious attempts at European settlement began on the river for almost another twenty years. The Dutch West India Company began a small trading post at later Hartford in 1623, completing a small fort a decade later on the eve of English settlement from the Plymouth and Massachusetts Bay colonies, which soon pushed out the Dutch.

To the immediate north, the area along Enfield Rapids was settled in a variety of ways from several directions. Windsor Locks began as a small outlying section of Windsor, a 12-mile-square town straddling the river. Families from Dorchester, Massachusetts began the permanent English settlement of Windsor in 1635-36, making it one of Connecticut's first three towns. These people edged out a group of fur traders from Plymouth Colony who had arrived in 1633, as well as small group arriving in 1635 with a patent from an English nobleman. Like many of the early river towns, Windsor began as a small fortified settlement near riparian meadows, in this instance at the mouth of the Farmington River, a major east-flowing Connecticut River tributary. Settlement quickly developed along a road parallel to Connecticut River meadows, and gradually dispersed along the Farmington's meadows as well. Alluvial meadows were the most immediately attractive cultivable areas for these English families, most of whom grew grain and managed small numbers of sheep and cattle. About a mile north of Windsor's northernmost houses, settlers farmed Pine Meadows' 60-70 acres by the early 1640s, in the southeastern corner of present Windsor Locks. Conflicts with Native Americans, and the relatively less attractive soils west and north of Pine Meadow, restricted English settlement in the Windsor Locks area to a few homes prior to c1750.

While the three first Connecticut river towns (Wethersfield, Hartford, and Windsor) were establishing a new government in 1636, William Pynchon established a settlement upriver at Agawam, later Springfield, with a party from Roxbury, Massachusetts. This was the first European settlement on the river above Enfield Rapids, and the basis for the later founding of Suffield and Enfield. Pynchon had to use canoes or wagons for any movement of goods beyond the rapids, and soon set up transhipment facilities at Warehouse Point, on the east side of the river below the rapids. Massachusetts Bay authorized his monopoly on fur trade with the upper river basin's Native Americans in 1638, and, in 1648, gave Springfield rights on the east side of the river to a point just below Pynchon's warehouse (Winch 1886: 139). Windsor's prior claim to some of this land was one of many boundary issues requiring over a century of argument and adjustment, the most notable of which was Massachusett's 1642 Woodward and Saffery survey which overextended the colonial border to the south by several miles.

William Pynchon's son John took over the family's extensive business and political responsibilities in 1652, and sought new outposts between Springfield, Warehouse Point, and the Connecticut river towns within the disputed area. Following land purchases from local Native Americans, he spearheaded the settlement of Suffield in 1670 and Enfield in 1679. Suffield was abandoned during King Philip's War, but quickly resettled in 1677. Windsor families moved east of the river after this conflict, establishing a separate parish in 1694 which included an area claimed by Enfield. Resolution of the boundary issues c1713-49 put Enfield and Suffield in Connecticut, and confirmed the limits between Suffield and Windsor, and Enfield and East Windsor; the latter community became a town in 1768. All four towns developed agricultural economies and relatively dispersed settlement patterns typical of 18th-century Connecticut river towns, exporting produce and livestock to metropolitan and West Indian markets. Warehouse Point, as part of East Windsor, remained a small but important transhipment center until well into the 19th century, and the only nucleated river community along the Enfield Rapids. Boat and ship yards operated here and in Windsor, and to a less extent just above the rapids in Suffield. Suffield's economy was somewhat diversified by the exploitation of local bog iron resources for several water-powered

bloomeries. Within Windsor, the Pine Meadows area became a small neighborhood of saw, grist, and fulling mills after 1750 (Tarbox 1886b; Winch 1886; Stiles 1892; Alcorn 1970; Lewis 1978; Anonymous 1954, 1976; see sections III.B, VII.A).

Federal Period increases in river trade, coupled with transformations in many regional trading and industrial patterns, spurred Hartford merchants to form the Connecticut River Company in 1824. Company goals included a canal around Enfield Rapids, control of all upriver navigation, and development of industrial waterpower sites along the canal (see section IV). Built along the west side of the rapids from 1827 to 1829, the canal initially had little impact on local communities other than a change of name from Pine Meadow to Windsor Locks in 1833, when the Connecticut River Company succeeded in honing the name of a new post office to meet its promotional ends. The company's transportation ventures were not profitable, and essentially evaporated after completion of Connecticut Valley railroads north of Hartford after 1844. Redirected company efforts soon made the Enfield Canal a source of waterpower for a mile-long row of textile, paper, and metal-forming or machine-tool operations which employed over 200 people by 1850, and nearly 350 people by the Civil War (U.S. Census Bureau 1850, 1860; see sections IV, V.D, and VII.A). The small industrial community which grew around the canal in Windsor Locks became a separate town in 1854, with the most concentrated array of factories and mills among the Enfield Rapids towns. Suffield and East Windsor remained generally rural communities focussed on commercial tobacco production from c1810-1945, with scattered paper, cider, gin, and textile mills at various times. Windsor Locks, Suffield, and East Windsor each had populations of between three and four thousand people by the turn of the century. Enfield, with approximately twice as many people, had the largest individual industrial sites in this area, at the Thompsonville (carpet) and Hazardville (gunpowder) mill villages which appeared by c1840. Community growth included the arrival and gradual integration of Irish, Polish, and Italian immigrants (Clark 1886; Anonymous 1976; see sections VII.A and VIII).

Although the beginnings of regional industrial decline removed some firms from Windsor Locks by c1930, there was little significant change in the size or work of the late 19th-century park area communities before World War II. Expanded road and airport facilities, and the Hartford region's growth in defence industry and commercial-insurance services, spurred population and housing increases which persisted until the mid-1980s. This growth occurred despite the diminished place of traditional industries. In Windsor Locks, the gradual disappearance of all but two canal industries by c1975 was offset by development in the largely unsettled western part of the small town, which became the site of Bradley Field/International Airport, new aeronautic products firms, and hundreds of new homes by the mid-1950s. Suffield and East Windsor, subject to declining tobacco land values, gradually transformed into predominantly bedroom communities, as did Enfield after the demise of the large Thompsonville carpet works in the 1960s.

The river and rapids gradually became less important to the river communities beginning c1850, as river traffic disappeared, bridges replaced ferries, flood control programs were introduced, and riverside industries closed. Only one firm, the Dexter Corporation's Nonwovens Division, now operates on the canal. Along the rapids today, some seasonal fishing persists, and there is undeveloped recreational use of the canal towpath. Geographic constraints, discussed in the next section, have inhibited much riverside development here, preserving a natural and built environment amenable to heritage park plans.

II. THE NATURAL SETTING

A. River and Rapids

The Connecticut River is New England's grandest and longest inland water resource, flowing largely north to south over 360 miles into Long Island Sound from "...a tiny pond a few hundred yards from the Canadian border, in the northernmost tip of New Hampshire...[draining an area of] about 11,500 square miles, encompassing parts of Connecticut, Massachusetts, Vermont, New Hampshire, and Quebec" (Bachman 1985: viii). Waters from this pond, Fourth Lake, fall some 2550 feet before reaching the Sound, but the principal headwater lies at an elevation about 900 feet lower, at First or Connecticut Lake (Bacon 1907: 348-50). Two thirds of the river's total drop occurs in the northernmost 60 miles, with the remaining fall generally more gradual. Along the 200-mile run of river from Barnet, Vermont to Hartford, the water drops about 400 feet (Erving 1925: 30), and below Hartford there is no appreciable drop for 49 miles to the Sound. The Connecticut is not only New England's longest river, but its longest tidal river, with a small tidal range (about 1.7 feet at Hartford) normally extending about seven miles above the state capital (U.S. Army 1917,I: 163). The earliest Dutch explorers called it the Fresh River (Versche rivier) because the strong downstream current tended to overcome the brackish tides, but the Indian name we use -- spelled at least 41 ways in Colonial documents -- translates roughly as "long tidal river" (Love 1903: 386-7; Bell 1985: 28, 79-80).

Through Massachusetts and about two thirds of its course through Connecticut, the river runs through a lowland surrounding the high longitudinal axis of the igneous Metacomet Ridge. The river crosses the ridge at Holyoke, creating a 50-foot fall, and flows east of the ridge through the lowland to around Middletown, where it turns southeast and leaves the lowland, cutting through Connecticut's eastern uplands to the Sound at Saybrook. The Connecticut River lowland environment is generally characterized by broad level surfaces in which the river and most of its tributaries meander with limited slope, except where the waters encounter higher bedrock deposits. Sedimentary, red-brown arkose or siltstone underlies the lowland at varying depths through Connecticut, below relatively small-sized glacial till which is well covered in most places north of Rocky Hill by level deposits associated with late glacial Lake Hitchcock. The lake drowned the lowland along 150 miles of present river some 13-16,000 years ago. Lake deposits included fine silts and clays later exploited for brick manufacture, and broad, sandy deltaic fans around tributary streams (Bell 1985: 13-20, 27, 32). After the lake drained, the river cut through the lake deposits, indifferent in most places to the erosible arkose, to create the gradual river slope seen in most of the lowland today.

Enfield Rapids stands out dramatically within this lowland river landscape. Beginning about 16 miles north of Hartford at the Enfield Dam, the rapids fall nearly 32 feet in about 5.25 miles, from about 36 feet above mean sea level (Porter 1885: 47; U.S. Army 1872: 837; Sheldon 1889; C E Maguire 1987). For most of this distance, from the dam to about the East Windsor north border, the arkose is exposed as high banks and forms the bed of the river. This is the only section of the river in Connecticut with either a rapids or exposed arkose, and even casual observers can see the rock as a landscape-forming agent, forming a hard, high-sided channel. It is also the only section in Connecticut with any potential for waterpower development, although construction in the river itself has always proved technologically and

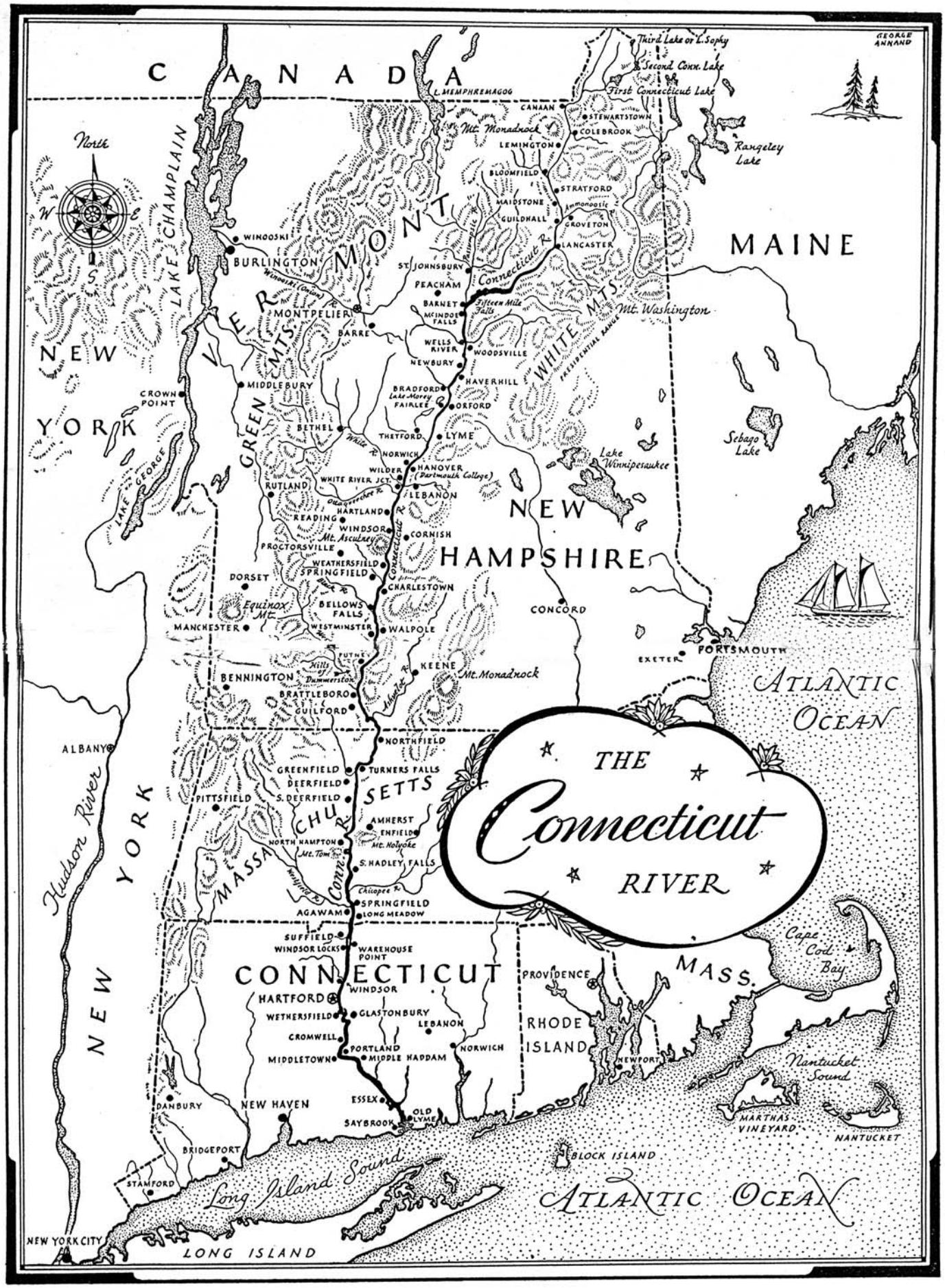

Figure 1
Source: Hard 1947

Figure 2.

PROPOSED PARK LOCATION & WINDSOR LOCKS CANAL FEATURES

politically daunting. The southern end of the rapids, at present Windsor Locks and Warehouse Point, originally had somewhat lower banks or narrow flood plains, with the arkose covered by alluvium. The lowland arkose generally occurs in north-south, east-tilting layers, and in other places is fine grained and erosible. At the rapids, a band of arkose more coarse grained and much less erosible passes under the river, creating a series of rapids rather than a uniformly-sloped or sharply-dropping falls. The river was probably prevented from flowing around this hard bed by bands of till on either side of the river, which confined the flow within a rock trench. King's Island rises above the rapids beginning about 2 miles south of their head, as a 100-acre tract which splits the river channel. The riverbanks, originally about 1000-1200 feet wide along the rapids, are up to 3400 feet apart around the island. This is the largest island in the Connecticut River which is completely surrounded by water, and is almost entirely bounded by high rock banks like those seen along the river edges, especially to the west (personal communication, Sidney Quarrier; Shel-don 1889; Colton 1960, 1965; Schnabel and Eric 1964; Hyde and Colton 1973; Handman 1973).

The rapids occur in sections of irregular length and fall, marked by occasional sand bars (e.g., Barnard 1827). Except in high water, they are navigable upstream only with great difficulty by shallow-draft vessels. A recent canoeist described one ascent:

> The sharpest natural drop in the riverbed at Enfield is about a quarter- mile downstream from the dam...the bottom being a sheet of red sandstone, smooth as a hardwood floor except for an occasional crack and a number of small potholes...The sheets of rock extended all the way across the river in a series of broad ledges, like a gradual staircase, each step a few inches high. This was the heart of the rapids (Bachman 1985: 30).

Above the rapids, the river runs over 18 miles to Holyoke as a level channel at least 4-5 feet deep. North of the fall and dam there, falls at irregular intervals divide stretches of relatively open water. South of the rapids, however, numerous sand bars or shoals fill undredged portions of the channel, with deepening channels from north to south. The 10 miles above Hartford is today the shallowest in the lower 59 river miles. Early colonial sailors approached the lower river with extreme caution, but gradually learned to navigate it with vessels suited to the channels above and below Hartford (Love 1903: 389-90). Except during about three winter months with river ice, the river was historically open to navigation of various sorts.

B. Channels, Flows, and Floods

High water in the Connecticut is not fully predictable, but usually occurs during spring melt-off, sometimes with back-ups of river ice, and during late summer-fall storms. Prior to 20th-century flood control projects, though, floods in January and February were not uncommon (Connecticut Rivers, Harbors and Bridges Commission 1913: 29). The exact timing of spring floods varies, but it "...was early discovered by navigators that every flood made some changes in the channel [below the rapids]. The very bed of the river has thus been moved in the course of time from east to west or west to east apparently at the river's caprice. The channel is filled more or less by every flood, and sand bars have been known to appear and disappear without due notice" (Love 1903: 400).

Normal high water prior to flood controls was about 16-20 feet above mean sea level at Hartford, with crests 2-5 feet higher at Windsor Locks. Some record of floods above these levels has been kept since 1639, although we have not seen any comprehensive studies (Love 1903: 400n.2; Connecticut Rivers, Harbors and Bridges Commission 1913: 29; Connecticut Groundwater Survey 1939; Hard 1947: 273-5; Anonymous 1954: 13-15). There is considerable circumstantial evidence that a wide array of historic development patterns altered the sequence, and eventually the height or volume, of high water. Cutting of forests and planting of crops changed the storage capabilities of the river basin, and tended to release more water into the river earlier in the year. By the 1850s, many observers believed "...that before the northern hills were denuded of their forests, there was a continuously greater volume of water in the river, which never became as low during the dry season as at present, although serious floods occurred as frequently as now" (Erving 1925: 30-5; also see Love 1903: 400n.2). In Windsor Locks, lower dry season flows became a particular problem for waterpower users (section VI).

Changes in flow patterns, exacerbated by the numerous dams erected on the river and its tributaries, may also have contributed to diminished channels through the shoals above Hartford. Allowing for the decline of river navigation after 1845 in the face of rail transport, the data reviewed for sections III and IV below offer qualitative contrasts between a period before c1850 when raft, flatboat, and small steamboats could navigate the shoals, and a period shortly thereafter when the Army Corps of Engineers consistently pronounced this section of river almost unusable. It is possible that altered flow patterns allowed for greater potential shoal build-up during high water silt deposition, and less potential for gradual silt removal or scouring with less low-water-season flow.

In the proposed park area, the Windsor Locks Canal acted as a *de facto* flood wall since its completion in 1829, and, along with the canal-side factories above the river, generally sustained the heaviest local damage during floods. Unlike other sections of the river, the high rock banks along Enfield Rapids inhibited extensive upland flooding. Sections of canal embankment frequently washed out through the 1850s, until the canal owners completed substantial repairs (section V). By the early 20th century, the growth of urban environments in the river basin, with more streets, diminished basin storage capacities further and contributed to the highest recorded floods in the river's history (1927, 1936, 1938 hurricane). Local Windsor Locks photographic, news-paper and company data are replete with details of high water and damage to structures and equipment. The highest flood, in March 1936, crested at over 40 feet above mean sea level in Windsor Locks, rising above the deck of the Route 140 bridge. Although the canal banks failed in several places in 1936 and 1938, and required preventive dynamiting at some spots to relieve water pressure within the canal, canal damages were relatively limited, reflecting the strength of the 19th-century embankment work (Anonymous 1936, 1938a, 1938b; Connecticut Groundwater Survey 1939).

C. Riparian Landscape

Prior to canal construction, most of present Windsor Locks consisted of a broad, level, sandy delta associated with deposits into Lake Hitchcock from the proto-Farmington River. These excessively well-drained sand plains, probably covered with pine forest when the Dutch and English arrived in the valley, were "...seamed with ravines..." created by post-glacial, east-running tributary streams of the Connecticut River, including Kettle and Pine Meadow (Waterworks) brooks (Hayden 1886: 561). Closer to the river, eroded terrace deposits and small pockets of glacial till abutted a narrow alluvial floodplain located between about the mouths of the two brooks noted, in the extreme southeast part of the town (Colton 1960, 1965). The richer floodplain soils, relative to those on the plains, attracted English settlers in the 17th century and Native Americans at un-documented earlier times. The English called the floodplain Pine Meadow, which became the core of present Windsor Locks (Hayden 1886; Stiles 1892,I: 492-3). Today, the east canal bank covers much of the original river edge in Windsor Locks, though some of the meadow terrain survives south of Interstate 91 (Figure 2).

Suffield and most of the east side of the rapids, in Enfield and East Windsor, have very different landscapes, characterized by the high rock riverbanks fronting north-south ridges of glacial till and broad river terraces. Suffield has virtually no alluvial lands, but is distinguished by extensive silty lake deposits between the till ridges, deposits which became extensively cultivated for tobacco. About 500 acres of the lake deposits became marshes, which provided bog iron for small-scale bloomery and forge operations into the early 19th century. Further west in Suffield, the ridge and low valley landscape runs into the high Metacomet Ridge, locally known as West Suffield Mountain. Several streams drain into the river from east-central Suffield, notably Stony Brook, which crosses under the line of the Windsor Locks Canal (Sheldon 1886; Colton 1960, 1965). The canal through Suffield includes an entirely artificial embankment built on the riverbed, east of the original rocky banks which are now partly obscured (section V). The outer side of this embankment, and small alluvial areas at the mouth of Stony Brook, are today covered in dense deciduous secondary forest and undergrowth. King's Island appears similarly wooded, and has been little touched for a century. It has particular visual appeal, and remains relatively inaccessible while being close to the west bank:

> Probably no other such charmingly isolated and secluded spot, so near to and yet so remote from the busy world, can be found in New England (Sheldon 1886: 384).

D. Fish and Wildlife

Away from the small urban center of Windsor Locks, the canal and riverbank environment today hosts migratory waterfowl, hawks,wintering American bald eagles, muskrats, and ground hogs. The small mammal population was probably established soon after canal construction, and is mentioned as a problem for canal maintenance by the 1850s Connecticut River Company 1856-69). We have not researched the bird population histories.

Although striped bass, sturgeon, and trout were once common in the river, the most important animal resources associated with the rapids historically are anadromous fish: Atlantic salmon, shad, and alewives (Burdett 1886: 5-6; Moss n.d.: 4). Hatched in freshwater tributaries of large streams and rivers, these fish spend much of their lives in the Atlantic Ocean, returning to their native grounds in the spring to spawn. Their annual spring runs in New England rivers were once a marvel, a piscatory bounty harvested by Native Americans and Euroamerican farmers. Salmon runs totalling 300,000-500,000 adult fish once reached at least twenty-eight New England river basins each year, with an estimated 70,000-140,000 in the Connecticut River:

> "Although at the southernmost end of the salmon's natural range, the Connecticut River may well have been the finest salmon river on the continent with runs among the largest in North America" (Foster 1991: 4, 142).

Numerous anecdotal accounts assert that the wealth of anadromous fish was such that they were not considered a luxury or even a very upscale food source in colonial New England until after c1750, and were valued as much for fertilizer as food (e.g., Stiles 1892, I: 502; Brainard 1951, Moss n.d.). This increase in value may reflect the diminishing numbers of fish as dam construction increased throughout the region.

The ability of anadromous fish to jump over obstacles was a major factor in their continued use of freshwater spawning grounds. As the best jumpers on the Connecticut, salmon reached at least Colebrook, New Hampshire, just below the river's principal lake sources, and entered many of the larger tributaries; shad never ascended above Bellows Falls (Brainard 1951; Moss n.d.: 4). It was widely recognized from prehistoric times that rapids and falls, where the fish were delayed in their spring river-climbing, were ideal places to spear or net them. Enfield Rapids was the first major obstacle on the main stem river above the estuary (also a major fish capture point in, at least, historic times), and has thus always been important to prehistoric and historic fishermen. In addition to presumed Native American use of the rapids, there is some evidence of established English use of fish pots and, on Stony Brook, fish dams by the early 18th century (Brainard 1951; Alcorn 1970: 38).

Artificial raising of river and stream obstacles for industrial waterpower development fatally disrupted anadromous fish life cycles, to an extent not fully overcome by more than a century of restorative efforts. Studies of other possible, natural causes for anadromous fish declines on the Connecticut River have found no factor so powerful as dam construction (e.g., Minta 1973; personal communication, Peter Minta). Initially, the Connecticut River's size inhibited dam construction, but, on smaller New England rivers, mill builders and farmers had to reach legal accommodations over fishing rights beginning in the early 18th century (Kulik 1985). By the mid-1790s, dams across the Connecticut at the Holyoke and Turners falls in Massachusetts began a rapid, catastrophic decline in the river's salmon population. Few salmon were seen or caught on the river by c1805 (McClure 1949; Brainard 1951). State fish acts, or other legislative protection of fishing rights, were inadequate to halt the salmon decline, because of the increasing strength of regional industrialists (Kulik 1985) and the inter-state course of the river.

Although diminished in numbers by the upriver dams, shad and alewives--some of which spawned in tributaries below Enfield Rapids--continued to be available. The 1829 wing dam for the Enfield Canal did little to change shad fishing. Suffield farmers caught fish, most likely shad, in the channel west of King's Island and in Stony Brook, often with elaborate cooperative netting and fish driving efforts among local families (Sheldon 1915: 17-19, 40-43, 55). Although the 1849 Holyoke dam introduced new obstacles to shad, they still apparently flourished downriver. In the mid-1850s, local fishermen protested the 1849 enlargement of the Enfield dam, and attempted to blow up the offending section in 1856, attesting to the continued value of shad (Connecticut River Company 1856-69).

By the end of the Civil War, however, the impact on shad populations of extensive gill or drag netting across the Connecticut River estuary contributed to regional demands for new regulation and restoration efforts. During the last third of the 19th century, the New England states began individual and collective attempts to require fishways in dams, restrict the nature and timing of anadromous fish capture by commercial operators, and restore fish populations through stocking programs. The influence of Connecticut's commercial fishing interests, and the occasional unexpected appearances of supposedly endangered fish populations, tended to dilute or thwart the efforts of the state's fish commissioners. A brief state shad stocking program c1867-69 had some success, and shad were able to use a fish ladder installed on the Holyoke dam in 1873. Despite much neglect, shad populations persisted on the Connecticut with minimal regulations, and continue to use the river today. Alewives, never subject to much formal assistance, have also maintained a presence which occasionally attracts commercial fishermen. Salmon could not use the 1873 Holyoke fish ladder, however, and regional hatching and stocking efforts disappeared by c1890. Since World War II, new fish ladder designs and renewed, federally-supported regional salmon stocking programs have begun to restore salmon to the river, but only at a very slow pace (Foster 1991: 5-9, 13-25; Moss n.d.).

Enfield Dam may have restricted some shad runs upriver, but it was apparently never a major obstacle, and became an important local shad capture point as it was gradually extended and raised between 1849 and 1881 (see section V.D). By the time the dam was modified in 1881 so as to have a uniform, slightly higher elevation across the entire river, the principal of requiring fishways or ladders was well established in federal as well as state courts; the U.S. Supreme Court had compelled the Holyoke Water Power Company to build one in 1872 (Foster 1991: 17-18). The 1881 Enfield Dam had a 40-foot-wide fishway at its center, which in one form or another has been maintained to the present. The dam thus allowed shad, and the few salmon in the river, to pass upstream, while slowing them down enough for fishermen who anchor boats below the dam or fish from the banks and canal headworks. As the dam has deteriorated rapidly since about 1976, its advantages as a fish capture point have diminished considerably (personal communication, Peter Minta).

III. RIVER TRADE AND TRANSPORTATION

The English colonists of the Connecticut River Valley quickly established roads and a few ferries or fords, often developing routes already used by Indians. Along the river, the earliest road above Hartford was on the east side, linking Springfield with Warehouse Point in the 1630s and with the Bissell Ferry in Windsor in the 1640s. By c1656, another path on the west side ran from Northampton to Hartford, passing through the center of later Suffield and Windsor Locks on the east edge of the level outwash plain (Stiles 1892,I: 497-8; Alcorn 1970: 2). Some goods and animals traveled on these and other roads across the interior, but the development of the valley after 1630 was closely tied to more effective transport of commodities, especially those with high volume or relatively low value. This section focuses on the sequence and nature of trade and transportation patterns. Section IV discusses navigational improvements intended to streamline some of those patterns.

A. Fur

Furs were a readily available commodity in the New World, and they had a high value in Europe. There was a surging demand for beaver fur in the seventeenth century, largely because of the fashion for beaver felt hats. Other furs were also eagerly sought, and even the skins of moose and deer had value for their leather. These furs represented an important source of income for colonies. After decades of haphazard trading by explorers and fishermen, individual traders or monopolistic companies from newly established French, Dutch, English, and Swedish colonies set up trading relationships with many of the eastern tribes. The existence of aboriginal networks of intertribal trade made it possible to expand the geographic area of fur collection far beyond the trading posts of the Europeans. A new and far more intensive trade economy covering great distances developed rapidly in the first half of the seventeenth century (Malone 1991: 36-37: Salisbury 1982: 55-56; Martin 1978: 61,100-102: Cronon 1983: 20, 90-99). Rivers played an important role as transportation routes, and were the scene of much trading among Indians, as well as between Indians and colonists.

The Connecticut River Valley was the center of fur-trading in New England. Indians in or near the valley were desperately eager for the European goods that they could get in exchange for furs. They wanted blankets, kettles, axes, knives, hatchets, guns, gunpowder, and other products or materials that colonists seemed to have in such great abundance. Trade became easier after 1627 when Plimoth colony, following the lead of New Netherland, decided to accept wampum, or shell beads, as a medium of exchange. Thomas Morton explained:

> We have used to sell them any of our commodities for this wampumpeag because we know we can have beaver again of them for it: and these beads are current in all the parts of New England, from one end of the coast to the other (quoted in Malone 1991: 38)

Tribes on the southern coast of New England, particularly the Narragansetts and the Pequots, began to produce wampum in quantity, making themselves well off by exchanging it for trade goods or for furs from inland tribes. As furs became scarce near the coast and along the easily accessible rivers, wampum and European products moved deep into the interior and furs came back. Overland trails and canoe routes led to and from the sources of wampum on the Connecticut, Long Island, and Rhode Island coasts (Malone 1991: 37-38; Salisbury 1987: 61-63; Thomas 1979: 169-184).

The area above and below the head of navigation on the Connecticut River, near the base of the falls, was soon a hotbed of trade and intercolonial (even international) competition. First Dutch, then Plymouth colonists and Puritans from Massachusetts Bay established trading bases. Dutch explorer Adrian Block had sailed up the "Fresh River" in 1614, and by 1623 the Dutch had an active fur trading enterprise at what is now Hartford. From 1623 to 1632, the Dutch apparently took at least 10,000 beaver pelts a year from the Indians who hunted, trapped, or traded for this resource. In 1633, however, Plymouth Colony moved into the region, establishing a post just above Hartford in the present town of Windsor. The colony was able to send "a great quantity of beaver" to England because of this post; it shipped 3,366 pounds in 1633. Two years later men coming overland from Massachusetts Bay established a farming community and trading post at Wethersfield. The Dutch were squeezed out by the English, and Plymouth authorities soon decided to abandon their trading post in favor of the new settlers from Massachusetts. By 1636, William Pynchon had brought more people from Massachusetts to found Springfield, seven miles above the Enfield Falls. He received a monopoly on the fur trade at Springfield from the Massachusetts General Court in 1638, then established another trading post at Woronoco (now Wethersfield) in 1640. After disputes with traders in Connecticut and at Woronoco, he established effective control of the fur trade in central and western New England, and retained freedom of transportation for his furs, agricultural commodities, and trade goods below the falls at "Warehouse Point" (Moloney 1967: 46-54; Bradford 1967: 257-260, 259-261, 280-284).

William Pynchon soon established a transhipment warehouse on the east side of the river at Warehouse Point, just below the rapids, probably about 650 feet below the present bridge crossing at Windsor Locks (Stiles 1892,I: 429). It first appears as "Cleyne Val" on the Jasper Danckaert/Visscher Map of 1650 (reproduced as Van Der Donck's Map of New Netherland, 1656), and appears a few miles south of "Mr.Pinsers" at Springfield (Jameson 1909: 294). Although there is no way to calculate the number or weight of pelts that William Pynchon shipped from Warehouse point to Boston, London, and other destinations, it is obvious that he had a thriving business which brought him great personal wealth. He did much of his trading using wampum as a medium of exchange, and even hired people in Springfield to string it for him. When William returned to England in 1652, his son John took over the fur trading monopoly (Bridenbaugh and Tomlinson 1985: 5-10, 20-24, 73).

John Pynchon left extensive accounts of his business dealings and a wealth of letters that provide insights into the operation of the fur trade (Bridenbaugh 1982; Bridenbaugh and Tomlinson 1985). Furs came from local Indians who hunted and trapped in the winter months, from middlemen in the villages of the region, and directly from distant

sources such as the Iroquois or the Mahicans in the Hudson River Valley (Thomas 1979: 176). John Pynchon relied more heavily than his father did on European agents who supplied large quantities of pelts. Between 1654 and 1667, Joseph Parson turned in 3493 pounds of beaver. Thomas Cooper supplied 3490 pounds in the brief period between 1652 and 1658. Pynchon packaged furs for transport from Springfield, Warehouse Point, and Hartford in wooden hogsheads and we know that he employed coopers in Springfield to make containers in 1664. Those hogsheads that contained nothing but beaver weighed between 254 and 325 pounds. There was also trade in fox, otter, mink, martin, lynx, muskrat, raccoon, deer, and moose (Bridenbaugh and Tomlinson 1985: 22, 35-38, 44-45; Armytage and Tomlinson 1969: 29-32; Innes 1983: 30).

The accounts show a total of 19,482 pounds of beaver shipped between 1652 and 1663. Data surviving from John and John Jr. on the period from 1664 to 1674 is not as complete; only 3152 pounds are recorded. After 1657 there was a sharp decline in the fur trade, as supplies dwindled because of overhunting. Wampum also lost its value, and formerly wampum-rich tribes in southern New England had to sell more of their lands to get trade goods. There was also a violent conflict in the 1660s between the Mohawks, who used to supply many pelts through intertribal trade, and the Pocumtucks who lived near the Connecticut River. Most of the New England tribes (but not the Mohegans) sided with the Pocumtucks and stopped trading with the Iroquoian Mohawks (Bridenbaugh and Tomlinson 1985: 47-55; Innes, 1983: 30; Salisbury 1987: 65-68; Trigger 1978: 352-354)

The heyday of the Connecticut River fur trade was over before King Philip's War began in 1675. This flowering was brief but statistically impressive. Thomas says that "By all accounts, barring Fort Orange and the Canadian posts, Springfield was the leading center for the fur traffic in the Northeast for over thirty years" (1979: 176). Most of that fur traffic passed down the Enfield Rapids in canoes for transhipment from Warehouse Point; and most of the trade goods that made the fur trade possible arrived by sloop at Warehouse Point.

B. Trade Networks for Agricultural and Industrial Commodities, c1635-1920

The fur trade was a highly specialized component of the valley economy for the first generation of settlement, and helped establish a regional system of distribution which thrived on English husbandry for nearly 200 years. Opportunities in fur trading and surplus crop production in alluvial areas quickly commercialized the larger Connecticut River Valley towns. Hired labor and the management of far-flung trade networks, along with artisan concentrations, characterized Springfield, Hartford, and Middletown soon after their settlement. In the 17th century, wheat, barley, peas, pork, beef, tobacco, pine tar accompanied the furs sent through Warehouse Point from the Pynchon region by c1650, and were shipped, along with similar agricultural commodities produced in the lower valley, to Boston, New York, other coastal cities, the West Indies, and occasionally Mediterranean or southern European ports. The extensive use made of barrels in this trade eventually created a thriving market for barrel staves supplied by upper valley areas. Hogs were generally slaughtered around the closest point of river transhipment, and packed salted in barrels. Cattle were sometimes driven to tidal ports such as Hartford, and there slaughtered and barrel-packed in brackish

water. Much of the export trade passed through New London, linked to the valley by ship, and by roads to Springfield and Hartford used for driving cattle and horses, the latter an important export to the West Indies. Barter dominated the exchange system, early imports from which included European finished goods and tools via Boston, New York, or New London; Caribbean sugar, molasses, rum, cotton, and salt; southern European wines; and small numbers of Black slaves (Burnham 1900: 141; Allis 1939: 80-5; Innes 1983: 6-10,33; Armytage and Tomlinson 1969: 29; Bridenbaugh and Tomlinson 1982: 105fn, 1986: 195-6).

Although agrarian commodities followed close upon fur exports, the end of the fur trade tended to diminish the mercantile role of the valley elite until the later 18th century. The Connecticut Valley's breadbasket status in the regional colonial economy was important, but the interior location of the river ports and centers left the much larger coastal cities in control of most trade in finished imports (Bailyn 1955: 53-5). As settlement pushed north, Springfield became less important as a collection point for exported upcountry products, but by the Revolution developed an important retail merchant group which traded overland with Boston and New York for high-value goods, and with Hartford or Middletown for the West Indian products whose traffic those towns came to dominate. Growth in the West Indian plantation economy, and Connecticut River shipbuilding in the 18th century, allowed lower-river merchants in river towns to export more produce and increasingly control West Indian imports. Lacking much direct connection with the sources of finished imports, the downriver merchants were heavily dependent on the West Indies trade, the early 19th-century demise of which redirected merchant resources into industrial, financial, and transportation ventures (Martin 1939:2,12-17).

These relationships persisted during a long period when river products -- the initial currency of exchange -- evolved and local retail distribution centers increased. By 1750, formerly-scorned shad were salted and exported, increasing the importance of local capture points on the river and its tributaries, including several in Suffield (Moss n.d.; General Executive Committee 1921: 126-7). Livestock products (sheep, fleece, butter, cheese) and high-value field crops like tobacco and onions gradually replaced grains, production of which was inhibited by soil exhaustion and foreign competition (Lewis 1978: iii, 106). West Indian molasses became the basis for a large valley rum-making trade by c1780, including many of Connecticut's approximately 500 distilleries (Allis 1939: 109). Foreign, especially British, trade policy contributed heavily to sharp downturns in the West Indies trade c1764-5 and c1783-93, but by c1790 regional and international events created a boom in valley commerce. In brief, widespread war in Europe re-opened the West Indies to American merchants, and the post-Revolution expansion of settlement in the upper Connecticut River Valley meant new markets for finished goods and new sources of export commodities. Upcountry lumber for shipping became a major component in river trade by c1800, along with freestone, shingles, hides, ashes, and potash (Hayes 1917: 56-9; Martin 1939: ch. II).

The boom, which lasted until the 1807 Jefferson Embargo, led directly to increased raft and flatboat traffic, shipbuilding including new yards between Hartford and Enfield Rapids, and the first serious plans for improved river navigation (see below and section IV. Distilleries and country stores also increased in this period. At Pine Meadow, the Haskell and Dexter families started a store near the new ferry to Warehouse Point, trading among other items in salt from Turks' Island in the West Indies (Hayden 1900: 26). Warehouse Point, still used for transhipment but less so in an era of flatboats which could pass the rapids in either direction, became a distilling center (see III.C below). The Embargo and the War of 1812 again disrupted trade, prompting some Hartford merchants to invest in small manufac-turing ventures, large numbers of which failed.

The decade following the Treaty of Ghent saw significant restructuring of regional commerce, focused on domestic rather than foreign markets. Britain again imposed restrictions on West Indian trade, which while still profitable no longer expanded, and British merchants dumped great quantities of finished goods on the American market to catch up with years of Napoleonic War constraints. For some valley merchants, profits fell greatly. Construction of larger British and American ships for international traffic drastically reduced the Connecticut River shipbuilding industry, limited by water depths, and the control of river merchants over trade. In particular, New York's growing role in maritime commerce, and construction of sail- and steam-powered craft, threatened to limit the role of valley merchants in distribu-tion of finished goods upriver (Albion 1939). Expansion of American settlement to the west into new agricultural frontiers, and the early success of the Erie Canal in New York (built 1817-25), promised to undercut the price of upriver products unless more efficient transport could be created. Middletown's maritime commercial sector did not withstand these problems, and collapsed during the uneven, sometimes depressed economic conditions of c1815-20.

When times had been better c1800-10, Hartford merchants had protected themselves, and undercut Middletown, with channel improvements in the lower river to create easier direct ship connections from Long IslandSound. Construction of a bridge over the river at Hartford by 1810 made navigation upriver by sailing vessels more difficult, further cementing the city's control of so much of the river's commerce below about Bellows Falls. Further north, however, river commerce was sufficiently uneven that overland trade from the valley in less bulky items frequently went to Boston or Portland, or to the Albany-Troy area via Lake Champlain and the Champlain Canal, opened in 1823 (Kirk-land 1948,I: 67-9). As the depression ended c1820, Hartford merchants diversified into wholesale dry-goods jobbing to replace the diminished import of West Indian commodities (Talcott 1886: 668), and to some extent into textile manufacture. They also joined in new transportation ventures to extend their commercial control over the upper valley, and over the downriver trade with domestic metropolitan markets. Much of the impetus for these plans was rivalry among cities which might gain control of valley trade, notably New Haven and Hart-ford (Kirkland 1948,I: 70-5).

These efforts, conceived in terms of regular steamboat traffic between the uppermost river and the great coastal ports, had mixed results, as we detail below and in section IV. Above Hartford, it proved impossible to unify a disparate network of small canals begun in the 1790s into a single system, the last and largest of which was built for Hartford men at Enfield Rapids (1827-29). Below Hartford, locally-owned steam packets and tugs competed for many years with boats from New York, and with the railroads which gradually captured most river traffic c1838-55. Bulk fuel products still travel by river to Hartford. Merchants from Hartford and Springfield participated in

rail and river projects, but only the Connecticut city ultimately benefited from both types of development. The differential success of river transport above and below Hartford ultimately pitted the city against later upriver interest in commercial navigation. By 1850, Hartford was a transhipment point among rail cars, downriver vessels, and some smaller upriver craft carrying unusual items such as gunpowder. Agrarian commodity movement was by this time a declining component of regional commerce, firmly rooted in industrial and financial enterprises. Logs for upriver paper mills remained the last commodities moved on the river above Hartford, from lumber empires far upriver to the dam at Holyoke which created a permanent barrier to river traffic. With the end of log runs c1915-20, Connecticut River trade above Hartford was handled entirely by rail or truck.

C. River Craft and River Traffic

Until railroads eliminated most water-borne freight, Connecticut River traffic patterns entailed rendezvous points for larger coastal or oceanic vessels and smaller vessels adapted to upriver conditions. From the Enfield Rapids north, the falls and calmer reaches on the river made connections between the upper valley and Long Island Sound impossible on any one type of vessel. The transhipment on which so much of the river trade hinged involved six major classes of craft at various times, most of which operated about nine months of the year:

canoes, adopted from the Algonquians by the English and used north of Hartford, c1640-1760;

log rafts, made of salable lumber and sometimes hauling heavy freight, used north of Hartford c1760-1860;

flatboats/scows, perhaps indigenous to the valley, used above Hartford for most merchandise c1775-1855, with a few used for coal transport until c1895;

sloops, widely used c1637-1810 between Warehouse Point and Hartford or Middletown, and less frequently to c1825 after the 1810 Hartford bridge opened;

larger sailing vessels, used c1635-1850 from Hartford or Middletown to coastal and foreign ports;

steamboats of various sizes, used above Hartford c1820-46 for passengers and c1820-95 for freight (with a marked decline after c1845), and used c1820-1935 from Hartford to coastal ports.

In addition to vessels, log drives in the river above Holyoke became increasingly important c1845-1915, in response to paper industry development.

1. Canoes

Until the 18th-century development of boats adapted to running Connecticut River rapids, birchbark and dugout canoes were the principal means of moving freight from Springfield to the head of Enfield Rapids for wagon portage to Warehouse Point. Although the English recognized the uncertainties of canoe use, the critical place of these vessels in the local economy led to regulations in Springfield protecting trees suitable for canoe construction. The

Pynchons hired two-man crews with large canoes to take casks of furs and other commodities downriver, and bring back finished goods. The 15-mile round trip to the head of rapids was typical, with high-water passages made over the rapids to Hartford in the spring or fall (Stiles 1892,I: 736; Burnham 1900: 136-8; Innes 1983: 10, 104-6, 108-9fn.; Bridenbaugh and Tomlinson 1985: 196).

2. Rafts

Small rafts were used for crossing the river from earliest colonial times, especially at ferry sites such as those discussed below (III.D.2). As settlement in the valley extended further north after c1760, larger log rafts evolved to ship lumber and other heavy goods downriver. Diminished forests in areas accessible to the lower river by c1800 increased the need for long-distance lumber shipments from the upper valley. Although incapable of rapid-running except perhaps in flood, rafts carried far more than canoes and involved minimal freighting costs: they were broken up and sold for lumber at journey's end in Hartford or Springfield. By the 1830s, rafts were probably the largest and most numerous class of river craft (Hayes 1917: 60; Allis 1939: 109; Kirkland 1948,I: 67-9).

Raft sizes varied but raft design and operation evidently changed little during the approximately 100 years of this craft's use on the river. Several sixty-foot trunks would be fastened together with wooden pins, driven through two-inch-thick planks into each log at the ends and in the middle. Each unit of this type was a `box', about twelve by sixty feet. Hardwood pins stuck up fifteen inches from the plank ends at each box corner, to brace oars and guide box movement. Short planks with holes, placed over the pins, yoked boxes together to form a raft, typically a structure two boxes wide by three long. Eighteen rafts, each with a two-man crew, constituted a division for travel, at least by the mid-19th century. One pilot per division guided the rafts, with additional pilots often taken on at raft-navigable white water or shoal areas. One box per raft had a rough board shanty or tent for dining room and kitchen, and for sleeping; unlike many flatboat crews, raftsmen generally lived aboard, tying up their craft along shore at night. Elevated oven stoves served for cooking. The somewhat unwieldy craft were navigated with long oars and poles, somewhat like the flatboats described below, until reaching rapids or canals. At such obstructions, the rafts were disassembled and the individual boxes were poled through or carted around for reassembly below. Portages could take up to three days, encouraging the growth of taverns and other village facilities at portage points. As railroads stretched upriver, common practice at portages involved taking half a division through, catching a north-bound train, and bringing down the other half. At the end of the trip, raft crews had to return home by other means, on trains or the flatboats which replaced them for most general freighting purposes (Hayes 1917: 60-61; Allis 1939: 109-10).

3. Flatboats

Small pole- and sail-powered flatboats of 2-to-3-ton capacities were first used above Warehouse Point early in the Pynchon period of trade, but until the Revolution they evidently did not appear in a 12-to-20-ton form which made them the most important commercial vessel type on the upper Connecticut (Love 1903: 402; Bridenbaugh and Tomlinson 1986: 196). They were the first vessels capable of passing rapids both ways

in most seasons, and thus the first larger freight carriers which could make return trips upriver, although some were broken up at Hartford for lumber. Sometimes called scows, the larger flatboats may have appeared very shortly after log rafts. By the mid-1780s, there was a steady flatboat traffic on the 180-mile-run between Hartford and Wells River, Vermont, at the end of most effective flatboat navigation; boats occasionally reached Barnet, another ten miles north. Wells River became a major freight transhipment point prior to railroad construction, and had the most important boat-building yard on the upper river. The Wells River-Hartford round trip took twenty-five to thirty days (eight going down); comparable trips took fourteen days (three down) from Bellows Falls (Hayes 1917: 56-9; Kirkland 1948,I: 67-9). This relatively rapid delivery of upcountry products encouraged more keg and cask production for increased shipments, but distances and river obstacles tended to restrict regular flatboat service north of the Deerfield River, from where a line of boats to Hartford was established by c1810 (Erving 1925: 30; Allis 1939: 127-8).

Prior to Enfield Canal completion in late 1829, some sixty to one hundred flatboats with 12-to-20-ton capacities operated on the river (Stiles 1892,I: 566-7; Abbe 1897: 266; Hayden 1900: 26). Too large to run downriver except in freshets or high water, these boats were still more profitable than smaller craft which could operate all year (Kirkland 1948,I: 67-9). Although the earlier locks above Enfield Rapids were generally smaller than those built by the Connecticut River Company, the fact that 30-ton-capacity boats operated below White River Junction by the 1850s suggests that trade volume rather than lock size was initially the limiting variable in boat size. River channel sizes limited most boats built above White River Junction, c1780-1855, to no more than 20 tons (Allis 1939: 127-9). The Enfield Canal allowed for the use of bigger scows with capacities reaching 60-75 tons c1855-95, towed by steamboats as far north as Holyoke. These larger sizes were, again, not simply reflections of larger lock size limits, however. Many boats continued running Enfield Rapids in this period to avoid tolls. Holyoke waterpower development precluded travel further north by smaller boats, and the decline of most river freight meant that remaining, lower-value waterborne bulk items such as coal had to travel in larger volumes for profitable shipping. A few scows remained in operation into the 1920s (U.S. Army 1925,I: 90). One exception to this latter pattern involved the Enfield powder mills, whose raw materials and products were considered unsafe for rail transport. Boatmen transferred these more dangerous items to Hartford for shipment on schooners (Dewey 1881: 117; Stiles 1892,I: 507-8; Abbe 1897: 273; Love 1903: 403; Sheldon 1915: 50-1).

The flatboats used below White River Junction were typically flatbottomed, oak board vessels with continuous gunwales, and one to three sails on a central mast; smaller flatboats built further north were often made of pine. Our sources have little detail on the older, smaller boats with capacities under 20 tons, but indicate these had narrowed ends and lacked cabins. The crews landed each night, or anchored near shore, and ate at one of the many taverns or inns along the river (Abbe 1897: 266; Love 1903: 404). The 30-ton-capacity boats used after c1830 were about 72-75 feet long, 11.5-15 feet wide, and had 10-to-12-foot wide ends. When fully loaded, they drew between one and three feet of water. Larger vessels, especially those exceeding 30-ton capacities, had cabins with stoves, perhaps reflecting a demise of riverfront taverns as the number of boats dwindled after c1855 (Hayes 1917: 56-9; Love 1903: 403-4).

Virtually all flatboats were sailed, poled or rowed before c1820.[1] Towing by steamboats south of Bellows Falls was common c1820-35, but did not eliminate the earlier propulsion methods which remained necessary above Bellows Falls and for many if not most down-river flatboat voyages. After c1835, steam towing persisted south of Holyoke, and propelled an increasing percentage of the larger flatboats in use to c1895. Poled-boat crews typically consisted of seven men, three to pole along each side plus a captain. Special pilots were employed for dangerous reaches, as on the rafts described above. When required, the polemen walked along the boat sides, pushing 14-to-20-foot-long hardwood poles with iron points or spike ends. Upriver travel was laborious and slow, averaging perhaps a mile an hour in calm reaches, and doubling the $10/ton downriver freight charge. At rapids without canals, extra "swift-water-men" were often hired, at a dollar a trip, with one poleman needed per ton of freight. With many upriver boats starting at once from Hartford with favorable winds, local swift-water-men could make four or five trips a day. At Enfield Rapids, all upriver freight over 12-15 tons on poled boats was carted to Thompsonville via ox or horse team. Sometimes upriver boat hauling at these rapids involved on-shore use of ox teams and ropes. Most local men involved in flatboat traffic lived on the east side of Enfield Rapids, where the channel is deeper. As discussed in section V, it appears that some upriver flatboats avoided the Enfield Canal and its tolls, despite the labor involved, because it may have been less expensive to hire the extra polemen (Hayden 1900: 26; Love 1903: 403-404; Sheldon 1915: 37; Hayes 1917: 56-59).

4. Sloops and Other Deepwater Vessels

The navigable but shoal-ridden, often shallow channel between Hartford and Warehouse Point limited the size of sailing vessels from early Colonial times to sloops, single-masted vessels rigged fore and aft, used between transhipment points on the river (Bridenbaugh and Tomlinson 1986: 196). Until the advent of flatboats, sloops carried most freight below the rapids, including gin and other commodities shipped from Warehouse Point or Pine Meadow. Even in the flatboat era, prior to 1810 the increase in traffic from the north led to increased sloop use, with up to sixteen counted at Warehouse Point in 1790 (Hayden 1900: 25; Love 1903: 404). Sloops remained important for transport below Enfield Rapids until the 1810 Hartford bridge made that town the new head of sailing navigation. An effective draw added to the bridge in 1818 may have extended the use of some sloops, but by c1825 steamboats probably replaced sloops for most shipping in the traditional sloop area.

Ketches and larger vessels sailed for coastal, West Indian, or North Atlantic destinations from Hartford and Middletown. Ships from Boston and New York took some of this traffic, but hundreds of Connecticut River ships were involved in the regional and international trade carried by sail until c1860, by which time sail had succombed to four decades of steam and rail tranport competition. The great majority of the river-built ships, including the sloops, came from some forty yards on the lower river, beginning with a 1648 ship completed at Wethersfield. Above Hartford, however, shipyards flourished as far north as Chicopee, where perhaps the first schooner built in American fresh waters was launched in 1747 and sailed over Enfield Rapids in a freshet (Burnham 1900: 135). Shipyards in Windsor began by 1723. At least one brig was built at the mouth of the Scantic River before 1750 (Stiles 1892,I: 428, 767). In response to the increase in river trade

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[1] The arrival of a horse-powered, paddlewheel flatboat at Hartford in 1784 was probably a novelty rarely if ever repeated (Love 1903: 396).

after c1780, more shipyards appeared there, in Windsor, and at Warehouse Point (Hayden 1900: 270; Allis 1939: 111-12). At the latter place, two shipyards each turned out four or five ships per year by 1806, ranging between 70 and 300 tons (McClure 1949: 14). Most of these upriver yards disappeared soon after Hartford's merchants created their new head of navigation in 1810, with most probably gone by c1820 (cf. Pease and Niles 1819).

One of the last sloops built upriver was constructed on the banks of the Enfield Canal in 1830, when Pine Meadow's Samuel Denslow (1791-1869) is said to have launched the 100-ton *Eagle* sideways. Sized for the canal locks, *Eagle* made only one trip above the rapids and joined the fleet of freighters still used downriver (Love 1903: 426-7).

5. Steamboats

The Connecticut River inspired several of the early developers of marine steam travel, including Windsor's John Fitch (1743-98) and his oar-propelled Delaware River craft (ran c1787-90), and Orford, New Hampshire's Samuel Morey and his side-paddle-wheeler. A version of Morey's experimental boat, first run on the Connecticut in his native state c1790, steamed from Hartford to New York in 1794 (Stiles 1892,II: 264-7; Erving 1925: 76-7; Albion 1939: 143; Hard 1947: 174). The establishment of steamboats on the river did not really begin for over twenty more years, however, following the one-time 1817 appearance in Hartford of the *Fulton*, the first regular passenger steamer on Long Island Sound (Erving 1925: 79; Albion 1939: 14). Operated between New York and New Haven c1815-22 by the interests of the boats' eponym Robert (1765-1815) and his backer Robert Livingston, *Fulton* represented two early constraints on Connecticut River steam travel from Hartford. A 1798 monopoly on steamers in New York waters held by Fulton and Livingston discouraged development of traffic from Hartford to New York, and the river valley apparently lacked the marine boiler- and engine-making expertise which emerged fairly quickly around the Port of New York.

Shortly after the *Fulton* appeared, Hartford merchants and other promoters of river navigation began active pursuit of steam transport, inspired in part by the beginnings of the prolonged legal battle in which the U.S. Supreme Court eventually broke the monopoly (*Gibbons v. Ogden*, 1824). The earliest active promoter of Connecticut River traffic was John L. Sullivan, secretary of the Middlesex Company, who wanted to apply that firm's successful use of steampower on the Merrimack River in Massachusetts and New Hampshire. Building on the Merrimack navigation of calm reaches between canal-circumvented rapids, using steam boats, Sullivan in 1818 proposed to consolidate freight service between Brattleboro and New York with three sizes of towing vessels adapted to upriver, downriver, and sound conditions. In the same year, he oversaw the first steamer built in Hartford, the timorously-named *Experiment*, operating it as a towing vessel between Hartford and Saybrook. Sullivan's plans included a canal by-pass of Enfield Rapids, the first so proposed, for which he received a state charter of incorporation, also in 1818. His charter expired without any canal construction, but his plans influenced better-financed efforts by Hartford merchants. He was also instrumental in passage of an 1822 Connecticut law prohibiting boats operating under the Fulton-Livingston monopoly from entering state waters, thus protecting nascent Connecticut steamer lines (see section IV; Connecticut General Assembly 1789-1836,I: 507-10; Love 1903: 405, 416-20; Erving 1925: 83-5; Kirkland 1948: 70-5).

Passenger steamboat operations on the lower Connecticut began in a limited way in 1819, at first under the newly-chartered Connecticut

River Steamboat Company. Downriver steamers proliferated after the 1824 Supreme Court decision and persisted for over a century (Jacobus 1956). We will not follow this history here, except to note that some Hartford merchants interested in upriver navigation were involved in these efforts, which included futile attempts to restrain rail development, as outlined below.

Upriver passenger steamboats had a much shorter history, c1820-46, although steam towing of barges or scows persisted late into the 19th century. A few small steamers may have been built for passenger and freight service on upriver reaches between rapids c1820-26 (Hayes 1917: 64-5), but the principal impetus for upriver steam traffic came from Sullivan's plans, and fears of a New Haven capture of upriver trade. Hartford's Connecticut River Company, chartered in 1824, created a comprehensive scheme for upriver navigation, including steamboat operations north to Barnet via uniform lock sizes at the rapids (see section IV). To demonstrate the feasibility of this plan, and generate political and financial support for its overall scheme, the company had the steamboat *Barnet* built in New York in 1826 and set it off for its namesake town. A flat-bottomed sternwheeler designed for upriver travel, *Barnet* was 75 feet long and 14.5 feet wide, and drew 22 inches unloaded (Hayes 1917: 65-6). In November 1826, after several failed assaults on Enfield Rapids, *Barnet* surmounted the rapids with the assistance of two flatboats and steamed on to Bellows Falls, where too-small canal locks stopped its triumphant movement north. Tremendous local excitement accompanied its voyage, which ended in a return to Hartford (Erving 1925: 107-26; Allis 1939: 147-53; Jacobus 1956: 15-17).

Although never again on the upper river prior to its 1827 demise by explosion, the *Barnet* set off a burst of plans and operations by the Connecticut River Company and private competitors (Erving 1925: 126-8). Occupied with Enfield Canal construction from 1827-29, the company did not become actively involved in steam traffic again until 1830. During this hiatus, Thomas Blanchard built and ran two passenger steamers at Springfield, *Blanchard* (1827-8) and *Vermont* (1829). Blanchard (1788-1864), an extraordinarily prolific American inventor, was completing his contract to mechanize many of the gunstocking operations at the federal Springfield Armory when steam traffic presented a new opportunity in 1827 (Cooper 1988). His namesake boat, launched July 1828, was a 4-boiler sidewheeler with a 60-passenger capacity, 60 feet long and 19.5 feet wide with guards and flooring. Capable of running the rapids, *Blanchard* carried passengers between Hartford and Springfield regularly for several years, occasionally running to the falls at South Hadley. Dissatisfied with her performance, and perhaps aware that she was too large for passage through any locks on the river -- including those on the nearly-complete Enfield Canal -- Blanchard built *Vermont* as a sternwheeler, 75-80 feet long, and 14-15 feet wide, drawing 12-15 inches. This second boat, with boilers and a horizontal-stroke-piston, 120-hp engine of wrought iron instead of the usual cast iron, was intended for runs from Hartford to above Bellows Falls. *Vermont* reached the Queechee Falls locks at Hartland, Vermont in August 1829, and operated unsuccessfully a few months between Bellows Falls and Windsor, Vermont before settling into regular Springfield-Hartford service. Blanchard and both his boats appearly prominently at the November 1829 opening of the Enfield Canal, when the older boat carried passengers from Hartford to the lower locks and *Vermont* was the first steam vessel to pass through the canal (Bullock 1900: 299; Hayes 1917: 64-71; Erving 1925: 148; Dayton 1925: 124; Jacobus 1956: 19).

Blanchard briefly enjoyed little if any competition for his passenger services, in part because stagecoach travel between Hartford and Springfield remained faster than his boats.In April 1831, the inventor launched a much faster, 2-engine boat, *Massachusetts*, the largest built in Springfield, which was too big for the Enfield Canal but could outrun anything on the river and work in some winter ice conditions. Blanchard obtained a patent to his new design, which proved threatening enough to local stagecoach operators Chapin & Deming that they quickly bought him out, running *Massachusetts* from July 1831 until she burned at Hartford in 1842. The new owners also ran Blanchard's two older boats, renaming the first one *Springfield* (Bullock 1900: 300; Dayton 1925: 125; Allis 1939: 147-53; Jacobus 1956: 20).

Shortly before her ruin, *Massachusetts* was probably the boat which carried Charles Dickens from Springfield to Hartford in February 1842, over the rapids, during the English writer's American tour. Dickens professed simultaneous alarm and admiration for his conveyance:

> It was certainly not a called a small steam-boat without reason...I should think it must have been of about half a pony power...I am afraid to tell how many feet short this vessel was, or how many feet narrow; to apply the words length and width to such measurement would be a contradiction in terms. But I may state that we all kept the middle of the deck, lest the boat should unexpectedly tip over, and that the machinery, by some surprising process of condensation, worked between it and the keel; the whole forming a warm sandwich about three feet thick.
>
> It rained all day...the river was full of floating blocks of ice which were constantly crunching and cracking under us; and the depth of water...did not exceed a few inches. Nevertheless, we moved onward, dexterously; and being well wrapped up, bade defiance to the weather, and enjoyed the trip (from ~~American Notes~~, quoted in Bullock 1900: 301).

This journey, made in unusual winter conditions for river traffic, probably took somewhat more than the usual three hours for the downstream trip offered by a growing number of steamboats after Blanchard's successes. Most boats avoided the Enfield Canal downstream, with some of the smaller ones using it upstream to conserve fuel. The upstream trip was typically about four hours. Daily passenger travel between Springfield and Hartford cost about $1.00/person each way, with half fare sometimes offered between Hartford and the lower canal locks. The sand bars above Hartford often required experienced prying work with boards to keep the boats afloat (Abbe 1897: 267; Hayden 1900: 31-2; Erving 1925: 187-9.Other prominent passenger steamers running c1831-46 included *John Ledyard, Phoenix, Agawam,* and *Greenfield*. *John Ledyard*, unlike most, ran from Springfield to Bellows Falls, and in 1831 had the distinction of reaching, once, the northernmost point of Connecticut River steamboat travel at Wells River. After c1835, there was no steam traffic north of South Hadley falls (Bullock 1900: 301-2; Erving 1925: 205). The railroad eliminated regular inter-city passenger service, although there was a brief resurgence in steamer excursion traffic in the Agawam-Springfield area c1920-25 (U.S. Army 1920,I: 188, 1926,I: 94).

Steam towing of flatboats or scows outlasted passenger service by about a half century, with a few boats probably running freight into the 1920s. Comprehensive freight projects succombed to the disparate nature of river navigation facilities. The Connecticut River Company attempted to control freight services shortly after completing its canal in 1829, and set up a subsidiary Connecticut Valley Steamboat Company in 1830 to implement its plan for a series of steam towboats on inter-canal reaches. Six shallow-draft steamers were built for

service between Hartford and Queechee Falls, with flatboats used for connections to Wells River. Irregular upriver canal operations, which the Connecticut River Company had never been able to consolidate, and high freight costs limited this operation to one season on most reaches, ending the company's dream of comprehensive upriver navigation (Burnham 1900: 147-8; Hayes 1917: 70-1). The completion of the railroad to Springfield in 1844, and the interest of some company directors in downriver steam transport with larger vessels, resulted not only in the shift from transportation to power canal operations discussed in section V, but in active opposition to later upriver navigation plans which might replace Hartford as head of steamer navigation.

Other less grandiose operations below Holyoke succeeded, however, with one or two large steamers and some small tugs. Some tow companies ran to the river mouth at Saybrook. The 50-ton *P.B. Goodsell* of Springfield was one of the most prominent tow steamers, and gained great renown for a trip during the May 1854 flood which rendered all rail and road links from Enfield Rapids to Hartford impassable. In one account of this trip:

> The *Goodsell*...lay at Warehouse Point [during the storm accompanying the flood], near the American Hotel...waiting to unload...When the storm abated, [she] made a landing on what is now Bridge street, several rods east of the hotel...[M]any of the business men of Windsor Locks, having bank-notes coming due, conferred together, and Chas. H. Dexter crossed the Connecticut to see if the *Goodsell* could be chartered to take a party to Hartford and back...As they neared Hartford [with a large party], the captain...sent two of his men ashore in a skiff to open the draw of the [Hartford, Providence, & Fishkill Railroad] bridge...On passing through, the west end of the Hartford bridge (recently burned) was seen to lay in the water, and the *Goodsell* went down through the East Hartford meadows *around* the bridge, and, coming back into the river, crossed over and steamed up State street to Doctor Bull's drug store...where it tied up, and the live freight made their way off the gang plank to terra firma once more. The United States mail was also brought down, and after business transactions were completed, the *Goodsell* brought her human cargo safely back around by the meadows to the place from which they started (Abbe 1897: 269-70).

Charles H. Dexter, president of the Connecticut River Company and owner of one of Windsor Locks' major paper-making firms, became the namesake before his death in 1869 of one of the last steamers to run on the river above Hartford. The Douglas family[1] built the 40-ton, 82-foot-long *C.H. Dexter* in 1866 at their boatyard in Suffield, and operated it along with some other vessels. Purchased by one of the larger downriver towing firms in the 1870s, *C.H. Dexter* operated until 1881, ending her career, after a serious accident, beached at Hartford's Dutch Point, where she was later buried by landfill (Bullock 1900: 302; Erving 1925: 203-5).

D. Crossing the River

Enfield Rapids were a barrier to navigation, but in some ways were a boon to river crossing. The hard high banks and rocky riverbed provided excellent bridge-building opportunities, and a ford just below the rapids was an unusual crossing point. Although not readily used over the rapids proper or in most winter ice conditions, ferries developed at many points from early colonial times to eliminate the river as a major hindrance to east-west travel for nine or ten months a year. People living along the rapids also found a variety of ways to reach King's Island, using ferry, ford, and river ice.

1. Fords

Large rivers were once major hindrances to ground transportation. They were barriers running through the landscape, and not easy to cross. Indians had to use canoes or find shallow stretches where they could wade from one side to the other, Colonists, lacking both the technological capability and the economic means to build more than a few bridges of substantial size, generally followed the Indian lead, Of particular value to the European settlers were the fords where even a wagon could cross a river, at least at low water levels.

Immediately below Warehouse Point at the lower end of the rapids, Connecticut's only ford across the entire river extended from just above the mouth of Kettle Brook on the west side to just below the bridge crossing sites on the east side. Although not documented, it seems likely that Amerindians used the ford long before English settlement. The channel was somewhat deeper on the east side, with the higher west side sometimes exposed as a low island known in the 19th century as Old Horse Pasture. Although accessible only in low water, the ford was used regularly well into the 19th century, even after a ferry was established nearby. The ferry actually required access to the ford when low water restricted boat access to the west side, and a stone wharf was built c1820 from the west bank at the ford out to the deeper channel. Ferry aprons could be dropped on a "gravel knoll" at the end of this wharf, on which passengers could walk. Horse teams forded between the end of the wharf and the riverbank. The wharf was in place until at least the mid-1870s, and may have survived through the era of ferry operation between Warehouse Point and Windsor Locks (Bailey 1877; Hayden 1886: 563; Hayden 1900: 81-4; Anonymous 1954: 15-16).

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[1] There was apparently no relation between this family and Dexter's brother-in-law Edwin Douglas, discussed in section V.

People with rights to King's Island often used it as a woodlot. At low water in the summer, the west river channel could be forded with teams from Suffield. Probably prior to the 1864 Terry purchase of the island, the canal bridge and the road to the King ferry site, noted below, provided the access to this ford. During the winter, the island was sometimes accessible from Enfield for wood hauling via "ice bridges" made by strategic placement of river ice; the precise methods used here are not clear (Sheldon 1915: 38-9, 54-5).

2. Ferries

The relative scarcity of reliable crossing points, and the importance of breaching the great river's barrier to commerce and civil order, made Connecticut River ferries subject to public control from early colonial times. Until the late 17th century, the nearest ferry crossings of the river were at Springfield and at the Bissell Ferry in Windsor, located near the mouth of the Scantic River. The latter crossing, authorized by the General Assembly in 1641 and operating by 1648, was among the earliest in the United States and ran until after the Revolution (Stiles 1892, I: 412, 497-8; Bachman 1985: 23).
In the Enfield Rapids vicinity, three ferries ran at various times: at Thompsonville; north of King's Island: and at Windsor Locks-Warehouse Point. The northernmost, immediately above the rapids near the present Route 190 crossing, was authorized in 1691 by the Hampden County Court. We have not fully documented its operation by the Alline, Trumbull, and other families, but it appears to have ceased operation when the Enfield Bridge was available after 1808 (Whittlesey 1938: 51; Alcorn 1970: 44; cf. Anonymous 1827). A steam ferry was revived here to compete with the aging bridge, c1858-93, and ran many years with the boat *Cora*; completion of the Thompsonville-Suffield bridge permanently halted ferry business here (Sheldon 1889).

The only ferry to cross the rapids was run by the King family of Suffield, about a half mile above King's Island. The King ferry origins are unclear, but it began before c1749, ceased after the nearby Enfield toll bridge opened in 1808, and apparently[1] did not revive later. The ferry was evidently not running in 1827, but the Connecticut River Company had to erect a swing bridge over the Enfield Canal for the ferry access road, suggesting that the ferry had run recently enough to require maintenance of its way. As noted above, this road also served local families who forded the river to the island (Anonymous 1827; Sheldon 1889; Sheldon 1915: 54-5).

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[1] The Enfield Bridge was essentially deconstructed for about fifteen years prior to its 1832 rebuilding, as discussed below. It is possible the King ferry revived sometime during this period, maintaining enough presence to require notice by the canal commissioners overseeing canal design and property damages. An important map of the canal as first designed shows the exposed bridge piers, and the Windsor Locks-Warehouse Point ferry, but only the *roads* leading to the King ferry site (Barnard 1827).

Although a charter was first requested in 1755, the Windsor Locks-Warehouse Point ferry was not authorized until 1782. James Chamberlain began operations the following year. Like other early river ferries, his was a flat-bottomed boat, perhaps equipped with a sail but generally poled or rowed. As noted above, low water conditions sometimes required use of the ford on the west side of the river. The Dexters and Haskells opened a store near the ferry in 1784, and the Town of Windsor established a road to the site in 1788. The store became a house for the ferryman, and was moved to the later bridge site after severe damage in the great ice flow of c1811-12. Barton M. Douglas, last purchaser of the private ferry in 1847, converted it to a swing operation by c1855 with the contruction in the river of a stone pier, from which a wire, connected to the boat, allowed the force of the current to move the ferry. In 1870, Douglas attached his ferry by pulleys to a larger cable that spanned the entire river, presumably using the same pier (The Connecticut Archaeological Survey 1988: 3-5). Within recent memory, a boulder visible in the river in this vicinity retained a ring said to have guided the cable (personal communication, Howard White). An undated photograph (Howard 1935: 300) and a print published in 1886 (Hayden 1886: 565) show the Windsor Locks and Warehouse Point Ferry complete with mast and loading ramp. The private Windsor Locks & Warehouse Point Bridge Ferry Company bought the Douglas ferry in 1885, and built the 1886 suspension bridge described below (Sheldon 1889; Stiles 1892, I: 504n.,564-5,741-2; Hayden 1900: 23; Anonymous 1954: 13-16; Lewis 1978: 116-18).

As at the King ferry site, canal construction required a bridge crossing to reach the ferry. The ferry bridge appears on several maps and views, and was probably a low swing structure (Woodford 1855; Baker and Tilden 1869; Bailey 1877).

Suspension of service in winter, and the difficulties in operation during low water, limited the value of the Windsor Locks-Warehouse Point ferry. People living on both sides of the river here must have welcomed the formation of a company in 1885 which built a spectacular suspension bridge.

3. Highway Bridges

The first bridge across the Connecticut river was built in 1784 at Bellows Falls, Vermont, followed by bridges at Windsor, Vermont in 1796 and Springfield, Massachusetts in 1805 (Allis 1939: 105; Delaney 1983: 63-64). In this era of wooden crossings, bridges of such scale often suffered from design and material problems, and were subject to fire damage. Springfield's bridge "...gave way under too heavy a load of arms from the United States Arsenal..." c1814 (Allis 1905: 105). In Connecticut, the width of the river below Hartford restrained bridge crossings until the last third of the 19th century, and Enfield Rapids attracted the earliest attention as a crossing point:

> It is an admirable site for a bridge, uniting, with a safe and secure situation, shallow water, rocky bottom, and facility of obtaining stone for ..piers (Pease and Niles 1819: 68).

In 1798, John Reynolds, who with others had secured a 1791 state charter to make the river navigable between Hartford and the rapids, returned to the legislature and was granted a right to incorporate "The Company for erecting and supporting a Toll bridge, with Locks, from Enfield to Suffield." The 1791 plan produced no useful results. To placate fears of flatboat and raft users that a bridge would obstruct navigation, Reynolds proposed a bridge plus boat passage over the rapids by a short canal and locks, or a shore channel. After a time extension in 1806, this company opened the bridge in November 1808, the first crossing of the river built in Connecticut. Fruitless attempts to locate or design the navigation features resulted in cancellation of these charter requirements c1808-9 (Connecticut General Assembly 1789-1836,I: 249-52; Love 1903: 404-5; Arnold, ed. 1990: 53; personal communications, Matthew Roth and Lester Smith).

The 1808 Enfield-Suffield bridge was a seven-span, exposed (uncovered) wooden truss, about 1000 feet long and 30 feet wide, carried on six stone piers built on river bedrock. It probably included arched truss spans. The "...elevated and bold banks of solid rock [required] on the west side...a descent to enter upon the bridge" (Pease and Niles 1819: 68). This landmark structure had a bumpy history. The builders used green timber which soon deteriorated, and by c1825 the bridge had fallen into the river or been removed, leaving only the piers (cf. Anonymous 1827). William Dixon of Enfield purchased the bridge rights and rebuilt the crossing in 1832 as a covered bridge, using the old piers.[1] Dixon and subsequent owners probably minimized maintanance on the bridge, which was guarded by a series of tollkeepers who sometimes practiced handicraft trades while waiting for bridge users. The Marsh family owned the bridge c1873-1903, but closed it in 1896 due to advanced deterioration (Sheldon 1915: 61-3; Whittlesey 1938: 50).

Four years later, part of the bridge came to a spectacular end in the flood of February 15, 1900. Packs of ice carried the eastern three truss spans downstream, carrying with it Hosea Keach, a railroad agent who also regularly checked the bridge for the Marshes, and had gone onto the closed bridge late that night to assess the situation. Briefly knocked unconscious, Keach awoke and miraculously succeeded in getting out of the closed structure, clinging to part of the floating bridge truss as it moved toward the railroad bridge over two miles downstream. Observers in Enfield quickly got word to railroad personnel in Windsor Locks. In an amazing case of good fortune, the floating bridge did not crash into the railroad bridge, from which rescuers dropped a rope to Keach as he passed below them. He was plucked from the floating wreckage of one bridge and hoisted onto the strong deck of another. The bridge continued downstream, preceded by telegraphed word to crowds of expectant onlookers around Hartford, who were disappointed when it ran aground on shoals north of the city (Sheldon 1915: 64-8; McCain 1986). About three years after this episode, the Marshes sold what was left of the bridge to the Windsor

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[1] Although serviceable until the late 19th century, the bridge's chief value to its owners may have been its claims against later crossings. Since the original charter included the exclusive right to build a bridge between the north boundary of Windsor and the state line, the Dixon family, which retained the bridge until 1873, secured $10,000 from the Hartford and Springfield railroad for the right to built the 1844 crossing described below. The Marsh family, which owned the bridge rights c1873-1903, received payments from builders of the Warehouse Point-Windsor Locks 1886 suspension bridge and the 1893 Suffield-Thompsonville bridge above the rapids (Whittlesey 1938: 49-50; DeVito 1964: 10).

Locks Telephone Company, which blew up most of what remained and used the location to support pylons from which telephone lines were hung (Whittlesey 1938: 50; Bell 1977: 219-20). The pier bases survive in the river, sprouting luxuriant growths of wild shrubbery and small trees.

Just over a year after the completion of the original Suffield-Enfield bridge, Hartford and East Hartford were joined by an arched truss bridge, also uncovered, which altered river navigation as discussed above. Master builder Jonathan Walcott, from Windham, erected this bridge, opened January 1810 and carried off in an 1818 flood. The famous bridge builder Ithiel Town, from Thompson and New Haven, immediately replaced it in 1818, creating the first known covered bridge in Connecticut (Allen 1957: 74). This bridge had a more substantial draw than the 1809-10 structure. It burned in 1895, and was replaced in 1907-08 by the surviving stone-arch Bulkeley Bridge (Erving 1925: 21-7; Roth et al. 1981: 91).

There was no highway bridge over the river at Windsor Locks until 1886. The above-mentioned bridges to the north and south offered alternatives to the Windsor Locks ferry, but distances were inconvenient and they had tolls. Two of America's greatest bridge-building firms worked on the new highway bridge in Windsor Locks: the King Bridge Company from Ohio did the iron stiffening trusses and towers; and Trenton, New Jersey's John A. Roebling's Sons Company made the main cables, vertical suspenders, and diagonal stays. Although J. W. Shipman of New York was chosen over a local firm to supervise construction, he probably relied on local masons and stone cutters to build piers, abutments, and anchorages (Anonymous 1886).

The cables were unlike those used in most large suspension bridges. Normally bridge builders formed cables from sets of parallel wires; but here the Roebling firm, departing from the well-known "Roebling System," began with twisted wire ropes, which were twisted again into bundles. Seven such bundles laid parallel and bound together at 7-foot intervals made up each cable of this bridge (Connecticut Archaeological Survey 1988: 7-8). The Roebling firm, in Trenton, New Jersey, was one of the nation's largest producers of wire rope, and it was surely much cheaper to start with machine-made, steel ropes than to build up each cable from strands of wire as Washington Roebling had done on the site at the Brooklyn Bridge. There, Roebling used a traveling wheel that was drawn across the entire span from anchorage to anchorage, carrying one loop (2 strands) of wire on each round trip.

The cables made of galvanized steel ropes were more than adequate for the length and the expected loads of this highway bridge. The center span (between towers) of 547' and overall length of 1150' did not compare with the great 1595.5' main span and the 3455.5' length of the 1883 Brooklyn Bridge (Anonymous 1886; Vogel 1983: 29) but this was still a large bridge by the standards of the day. Numerous prints and photographs of this structure prove that it was a grand victorian achievement, perhaps the most picturesque bridge that ever spanned a New England river (see Anonymous 1886 and Connecticut Archaeological Survey 1988).

The suspension bridge, which cost over $100,000 was much more reliable and convenient than the ferry it replaced. However, the tolls it charged were considered excessive. They were particularly disturbing to the growing number of motorists who felt that their mobility was being limited. The nearest free bridges were in Hartford (free since 1889) or Springfield. Public enthusiasm turned to resentment over the substantial profits of the bridge company. Herbert R. Coffin, head of C.H. Dexter & Sons in Windsor Locks, entered the state General Assembly in 1906 and by 1907 succeeded in securing an act to free all Connecticut River toll bridges. In 1909, the state took ownership of the bridge, paid a settlement of $93,500, and removed all tolls. The resulting celebration took the form of a parade, fireworks display, band concert, and "public jollification." The bridge was "decked with red, white, and blue bunting from one end to the other, and...outlined with more than 1000 electric lights" (Connecticut Archaeological Survey 1988: 9-11; Anonymous 1909; Allen 1957: 74).

As with the earlier ferry bridge, the new highway bridge required a complementary bridge over the canal. All bridges crossing a navigable waterway have to be either movable or high enough to allow boat traffic beneath them. Most of the light-duty spans over the Windsor Locks Canal, for access to ferries and manufacturing plants, were apparently movable or had movable sections. A pier and swing mechanism for such a bridge survives in the canal just above the Horton site. The highway crossing the river at the suspension bridge also used a movable structure. By 1913 there was a metal swing bridge here called the "Highway Draw Bridge" at the canal. It was a Warren through truss with a polygonal top chord (Connecticut Rivers, Harbors, and Bridges Commission 1913: 33).[1]

Although the suspension bridge apparently performed well for more than a decade as a public structure, the Connecticut Highway Department decided to replace it with a new steel truss bridge to be built by Connecticut's own Berlin Construction Company. Three officials from the famous Berlin Iron Bridge Company had formed this independent bridge fabrication and erecting firm when their old company was acquired by the American Bridge Company in 1900 (Roth 1981: 68-70). Work crews finished the new seven-span, rivetted Pratt truss bridge in 1921. It apparently took years for the state to begin demolition of the suspension bridge, which was still standing downstream of the truss bridge in a 1924 photograph (Connecticut Archaeological Survey 1988: 1-2, 4, 11, 12).

Now the truss bridge is coming down, and with it most of the surviving ruins of the demolished suspension bridge. A new, and much wider, highway bridge will sweep over the river in the same location. The original stone abutments/ anchorages were demolished during this ongoing construction project, but examples of the bridge cables and the iron saddles that guided them have been informally preserved (personal communication, David A. Poirier).

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[1] The deck bridge over the canal today at this site is also technically movable, although it has been fixed in position for years.

The next bridge site developed near the proposed park area also replaced a ferry, at the Suffield-Thompsonville crossing. Berlin Iron Bridge Company erected this structure in 1892-93, about 4000 feet north of Enfield Dam. The five-span, steel through truss bridge (based on the Parker truss pattern) was 1064 feet long. Its construction led directly to the decision to close the Enfield-Suffield covered bridge. This structure survived until 1971, when it was demolished after the 1967 Veterans Bridge on Route 190 bridge diminished the older crossing's value (Anonymous 1892-93; U.S. Army 1905: 939).

4. Railroad Bridges

Railroad service came to Windsor Locks in the early 1840s, providing a great stimulus for economic development. When railroad builders chose a route from Hartford to Springfield for the Hartford & New Haven Railroad, they decided to cross from the west to the east side of the Connecticut River at Windsor Locks. The hard sandstone that helped to form the Enfield Rapids was ideal for seating the foundations of the proposed bridge, and the river was neither too wide nor too deep at that point. The railroad had to pass over the Enfield Canal as well as the river, but the relatively narrow canal and its towpath did not require long spans. In the first of four structures here, an 1844 wooden structure included two through trusses (140 and 76.5 feet) spanning these obstacles. A series of seven, 177-foot deck trusses (trains ran on top of them, instead of through them) crossed the river itself, supported on six stone piers with spans. There was a short 43-foot span at the west side of the river designed for a "draw", or movable section, if that should ever prove necessary, and another short span over a roadway on the east bank. In all, the bridge was 1524.5 feet long. Both the through and deck trusses were covered with sheathing boards to protect the structural framing from the weather. Masons built the abutments of granite, but at least two piers at the western end were of Portland brownstone (DeVito: 43-44; Ellis 1866: 15).

Erected under the supervision of Frederick Harbach (DeVito 1964: 43-44), the 1844 truss bridge was based on the 1840 patent of William Howe. The Howe truss combined the timber framing of earlier American truss bridges with an advanced use of wrought iron tensile members:

> The trusses were Howe's patent, consisting of top and bottom chords of timber, connected by inclined braces and counter braces, with vertical tie rods of iron (Ellis 1866: 12)

Howe had personally supervised the construction of the Western Railroad's bridge across the Connecticut at Springfield in 1841, and this nearby example must have influenced the design decisions at Windsor Locks. By 1850, wood and iron bridges of the Howe type had become the standard form for most railroads (Plowden 1974: 38-39).

The great sail area presented by the covered trusses of the 1844 bridge was probably most responsible for its untimely demise just two years after completion. A terrible gale in 1846 completely wrecked it, the trusses being "blown bodily off the piers into the river, for want of proper fastenings to the masonry" (Ellis 1866: 12).

Amasa Stone Jr, a resident of Springfield and a brother-in-law of William Howe, enlisted the aid of lumber mills throughout the valley to rebuild the bridge in the short period of 45 days (DeVito 1964: 43-44, Darnell 1984: 83). Harbach, who had built the ill-fated wood and

iron bridge in 1844, received a patent in 1846 for an all-iron variation of the Howe truss. In an amazing twist of fate, it was an all-iron (cast and wrought iron) Howe truss that ruined the impressive engineering reputation of Stone thirty years later. A bridge built by Stone at Ashtabula, Ohio, collapsed in 1876, causing the deaths of 92 train passengers. Stone and the all-iron Howe truss received most of the blame in the inquiry that followed, a judgment that some historians of bridge technology now find unfair (Plowden 1974: 67-68).

Other types of iron bridges fared better, proving to be stronger and more durable than wood (or wood and iron combinations). One of the most ambitious railroad bridges of the post Civil War period replaced the wood and iron Howe truss spans at Windsor Locks. The Hartford & New Haven Railroad accomplished this replacement on the same line as the original bridge in 1866 (Ellis 1866: 13).

Because of the demands on American iron manufacturers during the Civil War, most of the ironwork for the new bridge was supplied by the famous British firm of William Fairbairn & Co. The truss bridge was made of wrought iron, and it utilized advanced technigues of rivetting which were still unusual in the United States. Half of the 175,000 rivets were installed by machinery in Britain, but the rest were heated, placed, and hammered by hand on the site:

> It is a long and tedious process to drive so many rivets by hand...At the time the work was commenced it was exceedingly difficult to procure riveters in this country who were accustomed to the heavy rivets used in bridge work. Ten English riveters were brought over by the company, five of whom soon returned. Others were found to supply their places, though it is a little remarkable that most of them were foreignors; Americans not seeming to take a fancy to this department of iron work (Ellis 1866: 29; Rosenberg and Vincenti 1978: 30, 39, 67-68, 73-74.).

The railroad bridge incorporated several variations on the Pratt truss invented in 1844. It had one triple intersection Pratt truss (the 177-foot channel span), thirteen double intersection Pratt trusses (sometimes called Whipple trusses) and one standard Pratt truss (the towpath span). James Laurie, a civil engineer from Hartford, designed the bridge in 1862. He also traveled to England to contract for the iron work and conducted strength tests on the selected wrought iron. Perhaps the most impressive feature of his engineering plans was the provision for construction without any disruption of existing rail service on this profitable section of rail line (ibid.: 14, 34; Comp and Jackson 1977: 3-8).

Because both the old and new bridges were single tracked and on exactly the same line, it was necessary to build one bridge in the space already occupied by another, without obstructing any of the trains that came through on an average of every thirty minutes during the work day. Laurie ordered his masons to raise the existing piers of the 1844-1846 bridge with additional stonework, using Massachusetts cut granite for all but the two Portland brownstone piers. The old masonry thus formed part of the support for the new bridge. The conservative engineer also added a new granite pier to all but one of the 177-foot river spans, producing twelve 88.5-foot spans and leaving a 177-foot channel span. There was also a 140-foot span over the canal and a 76.5-foot span over the towpath, as in the original bridge. Only the canal span was a through truss. Other than the short "draw" and roadway spans (both plate girders), all the other spans were deck trusses. The iron trusses for the river spans were

actually assembled inside the existing bridge trusses. In some cases support from temporary wooden trestles was necessary, but usually the existing trusses were simply strengthened to carry the additional load. Throughout the six months of construction, workers struggled to clear the tracks of all equipment and materials whenever a train approached (Ellis 1866: 11, 13-15, 19, 22-27, 34, figures; Powell 1905: 938).

After the bridge opened, civil engineer Theo Ellis wrote a report in which he concluded that "It is believed to be one of the best, if not the very best iron railroad bridge in the country." He also commented on the successful construction project: "The business of the road has not been interrupted for a single day; not a train has been delayed by the work, nor has any serious accident occurred to the workmen (Ellis 1866.: 34-35).

Despite Ellis's 1866 statement that "With proper care it will last a century," the railroad decided to replace the wrought iron trusses soon after the turn of the twentieth century. The single track over the bridge had become a serious limitation for the normally double-tracked route of the New York, New Haven, & Hartford. Also, the use of steel in a new bridge would allow much higher load limits. The railroad rebuilt the canal and towpath spans in 1903,[1] and the rest of the bridge in 1905. Once again, creative engineers found a way to keep the line open without erecting a separate bypass; a temporary pile trestle was considered and rejected as too expensive because of the necessary length (Anonymous 1905: 245-246).

This time the existing masonry piers were lengthened to support two tracks. During the first phase of construction, the old track was used both for normal traffic and as a means for transporting construction materials and equipment. Once one of the new tracks was in place on the lengthened piers, the older track was dismantled and the second track put in its place. Twelve deck plate girders replaced the 88.5-foot trusses of the old river spans, and a pin-connected, sub-divided Pratt (often called a Baltimore) through truss replaced the 177-foot channel span. The canal span of 139 feet is a rivetted double intersection Warren through truss with sub-struts (Ibid.; Office of the Chief Engineer 1974: 16; Comp and Jackson 1977: 7-8).

The unusual characteristic of the existing bridge is its direct connection to a sequence of earlier bridges. The position and overall length of the bridge has not changed significantly since the first spanning in 1844. Most of the original stone work for piers is still in place. The adding of intermediate piers in the river during the reconstruction of 1866 and the lengthening of piers for the double track bridge of 1905 left much of the early masonry intact. The bridge still spans the canal and the main channel with trusses of almost exactly the original length. This is a twentieth-century bridge with many mid-nineteenth-century features. It demonstrates beautifully the steady evolution of bridge design.

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[1] Charles E. Smith, then a bridge draftsman with the railroad, designed the steelwork for the canal span (mss. memoir, in possession of his son, Lester Smith, Suffield).

E. Railroads

In the 1820s duel between Hartford and New Haven merchants over water transportation routes to tap the products of the upper ConnecticutRiver Valley, Hartford interests took the first round by building the Enfield Canal and operating steamer lines (sections II.D above and IV below). This was initially a battle between mercantile elites. Even as the Enfield Canal was first opening, however, somewhat different New Haven transportation and manufacturing interests, led by carriage-maker James Brewster, were projecting a new mode of transportation rejected by the "Riverites." The Connecticut River Company had investigated the potential of railroads in 1826, even sending a committee to England to gather information, and concluded that the higher initial costs of a railway vs. a river navigation system did not warrant serious attention to the former:

> "...we think the subject of a rail-way may safely be dismissed from consideration...inasmuch as the cost of the proposed improvement of the navigation, is estimated at less than half the stated average expense of railways; as the navigation by steam boats with a velocity of four miles an hour, is equal to the wants of this section of country, and may be maintained on the river with no greater power than that required on a rail-way" (Connecticut River Company 1826: 53).

Led by Brewster, the Hartford and New Haven Railroad Company was chartered in 1832, overcoming opposition by turnpike and steamboat interests, and after extensive planning linked the two cities by rail in 1839. As first built, the line's traffic potential was limited. Connections from New Haven to New York City or Boston, or Hartford to Springfield or Boston, were then possible only by steamer or stagecoach. The railroad quickly established terminal connections to New York with the New Haven Steamboat Company, but was unable to reach the Hartford waterfront in the face of opposition by the river and steamer navigation interests. Hartford & New Haven engineers and directors knew that until Springfield was reached, the line could only tap local traffic, and then principally when the river was frozen. The incentive to reach Springfield increased as that town was linked by rail to Boston and Albany, between 1839 and 1841.In 1842, the Hartford & New Haven chartered a subsidiary Hartford and Springfield Railroad Company, which was completed in 1844 with the dramatic effects on river traffic discussed elsewhere in this report(Ayres 1886a:559;Frisch 1972:19;Turner and Melancthon 1986: 18-23).

Hartford's steamboat line owners, including men with interests in the Connecticut River Company, attempted for several years to fight the line to Springfield by attacking the New Haven and Hartford's critical link to New York, at the other end of the line. The Connecticut River Steamboat Company, largest operator of boats between New Haven and Hartford, successfully competed with the New Haven Steamboat Company and soon purchased the smaller firm. Once in control of steamer traffic from New Haven to New York, the Connecticut River line put its worst boat on the New York run and lowered its freight rates on the river. This tactic was futile. The railroad simply secured a state charter for its own boat line, and bought a steamer by 1847 (Kirkland 1848, I: 236; Turner and Melancthon: 23).

The following year, the New York and New Haven Railroad was completed, challenging traffic from the older set of rail and steam interests by leasing the New Haven and Northampton Railroad, completed from New Haven to Plainville at this time by some of New Haven's defeated but persistent "Canalites." The potential use of the "Canal Line" waterfront property for terminal facilities, and the potential threat of a new upriver connection if that line was completed to Northampton, quickly rearranged existing competitive arrangements. An uneasy truce developed between the two railroads, which shared traffic and a

terminal at New Haven c1850-56, and a working relationship evolved between the New Haven & Hartford and the Connecticut River Steamboat Company, helping the latter firm to fight the Sanford and Vanderbilt lines for many years before succombing to J.P. Morgan. The new relationship included a New Haven & Hartford waterfront spur in Hartford, securing that city's ultimate triumph in the river trade and turning its face forever downriver in later navigation project rivalries. The railroad not only captured most of the upriver trade; it severed the older links among up- and down-river steamboat interests (Kirkland 1848, II: 80-1, 134-5; Turner and Melancthon: 23-4, 60-64; see sections III.C and IV).

The New Haven & Hartford's line to Springfield ran west of the river through Windsor Locks, passing immediately between Main Street and the canal, and crossed the river at the Suffield border to Enfield on the bridge discussed above. Initial surveys for the route involved continuing the line north through Suffield, but the town objected to the new iron beast so close to an established road. By 1868, the advantages of a rail link to the Windsor Locks station were clear, and a group of local investors incorporated the Windsor Locks and Suffield Railroad. The Hartford & New Haven bought this line c1871 prior to its completion, and finished it to provide passenger and freight service; this spur is still used for freight. At about this time, just prior to the 1872 consolidation of the rival New York & New Haven and New Haven & Hartford lines, the river line was double-tracked. The principal local changes in rail service after the consolidation were the construction of the extant Windsor Locks station c1875, and the delivery of coal to the canal-side industries in the 1890s, after Congressional passage of a short-haul bill prohibiting higher freight rates to Windsor Locks than Holyoke. Coal freight prices were an important factor in upriver navigational issues afer 1865, as discussed in section IV. With the decline and fall of the New York, New Haven, & Hartford, and of most Windsor Locks industries along the canal, only very limited train service is available here, from a commuter parking lot south of the canal near Interstate I-91 (Hayden 1900: 31-2; Alcorn 1970: 136, 172; Turner and Melancthon 1986: 25).

F. Trolleys

The directors of the New York, New Haven, & Hartford Railroad generally took an acquisitive approach to alternative or competitive transportation ventures: they bought them. By the end of the 19th century, they had captured all but one of Connecticut's other railroads, and most of its steamer fleets. In the first decade of the 20th century, under the firm hand of J.P. Morgan, the great consolidated company absorbed most of the state's newest form of public transportation, local electric railways which had emerged in the 1890s. In the vicinity of the proposed park, the earliest trolleys opened on the east side of the river, linking Hartford and Springfield via East Windsor and Enfield in a series of phases from 1893 to 1902, from which the Hartford & Springfield Street Railway Company emerged. Between 1901 and 1904, two local companies in Suffield and Windsor Locks (Suffield Street Railway and Windsor Locks Traction), respectively connected the Suffield town center with the state line, and that center with Windsor along a route including North Main Street and the strip in Windsor Locks between Main Street and the railroad.

Hartford & Springfield Street Railway, which may have been somewhat independent of the New York, New Haven & Hartford, soon purchased Windsor Locks Traction; the NYNH&H trolley subsidiary, Consolidated Railway Company, acquired Suffield Street Railway. Following the typical American experience, the local trolley lines succombed to auto and bus traffic in the mid 1920s, disappearing entirely by 1926. Resurrected traces of the network survive at East Windsor's trolley museum (DeVito 1973; Turner and Melancthon 1986: 221).

IV. OVERVIEW OF RIVER IMPROVEMENTS AND CANALS

Merchants and vessel captains recognized the navigational limitations of the Connecticut River from early colonial times. Enfield Rapids separated the lower river, with problems of shallow channels and sand bars between Middletown and Warehouse Point, from the upper river where rapids were the principal issue. The upper river included some stretches of shoals where pilots were needed, but these required relatively little attention in improvement plans: upriver craft used before c1850 had very shallow drafts, and by c1850 construction of railroads and the large dam at Holyoke made upriver navigation potential extremely limited. Improvements on the Connecticut were generally inhibited by the multi-state disposition of the river basin, and by the different, often conflicting ambitions of upriver and downriver interests which vitiated public support for many projects. Lack of centralized control over navigational improvements stymied traffic (section III), and made it all the easier for railroads to strip the river of freight. Until after the Civil War, when the Army Corps of Engineers was handed responsibility for many river basin problems, the Connecticut River Company was the only organization to plan comprehensive navigation programs, albeit limited to the upper river.

A. Upriver Locks, Dams, Canals, and Other Improvements, 1790-1830

The renewal of the West Indies trade, and the expansion of settlement in the upper valley after the Revolution, led to the earliest attempts to improve the upper river. Between 1791 and 1810, during the heyday of this trade, private companies planned and built five short canals around all the falls on the river from Olcott's Falls, about two miles north of White River Junction, to South Hadley. Each of these projects required charters from at least one state. The steep drops, generally exceeding the fall at Enfield Rapids over much shorter distances and requiring some rock cuts, made these canals extremely expensive relative to their short distances.[1] The private firms involved were unprofitable for many years, but most saw at least some black ink. By 1850, all these canals were abandoned or converted to waterpower use (Connecticut River Company 1826: 12-29; Love 1903: 406-15; Hayes 1917: 73-7)

CONNECTICUT RIVER CANALS ABOVE ENFIELD RAPIDS

Name	Construction Period	Length(s)	Structures and Dimensions
South Hadley	1793-4	2.3 miles	1 dam, inclined plane, canal 40'x16'
(conversion)	c1805	"	locks: 5 lift, 1 guard, 18-20'wide; 4 wood, 2 stone
Miller's Falls	1793-1801	3 miles	8 wood locks, 2 dams; canal 20'wide
Bellows Falls	1792-1802	.75 mile	7 locks, 1 dam; canal 18'wide
Sumner's/Quechee Falls	c1796-1800	<1 mile	2 locks, 1 dam; no other data available
White River/Olcott's Falls	1810	<1 mile	5 dry-laid stone & wood locks, 70'x14.5'; 2 dams

Aside from some design or material problems, the principal limitations of this haphazard system were the non-uniform lock sizes, and the remaining smaller rapids, meanders, and shoals which received little or attention. The works at South Hadley were unusual in this regard, including a shore channel and towpath along the Willimansett Rapids, below the 50-foot-drop falls flanked by the principal engineering structures. The nature of the obstacles here and the somewhat better

[1] Available prices/mile include about $35,000 at South Hadley, $50,000 at Miller's Falls, and $140,000 at Bellows Falls (Love 1903: 406-14: Hayes 1917: 74-7). Enfield Canal cost over $36,000/mile, and was itself more expensive than most canals finished in the 1820s (see section V). We have not attempted to assess the relative values of the c1790-1800 and c1820-30 dollars.

financed nature of the venture, backed with much Dutch money, explain some of this case, atypical for upriver work (Love 1903: 406-11).

In Connecticut, Enfield Rapids presented the longest but most gradual of the river's major obstacles. The absence of improvements here, for a generation after the projects upriver, probably derives from the passable nature of the rapids with flatboats, the relatively great length required of any significant improvements, and confidence by Hartford merchants in good times that geography would continue to enrich them without such investment. The earliest plan, noted above regarding the first Enfield-Suffield bridge, involved a 1798 state charter to John Reynolds and others to lock around the rapids. Unable to raise capital, and understandably more interested in the immediately practicable toll bridge, the "Company for erecting and supporting a Toll bridge, with Locks, from Enfield to Suffield" made no river improvements and succeeded in removing requirements for canals or, later, a shore channel from its charter (ibid: 404-5; Connecticut General Assembly 1789-1836,I: 249-52). We have seen no details of any planned improvements under this venture, but given evolving, often successful American navigation technology at that time we assume that intent and money was more a problem here than engineering.

The pre-1810 Connecticut River canals were among the earliest built in the United States. The original work at South Hadley included a water-powered inclined plane capable of carrying loaded boats, designed by Benjamin Prescott, later superintendent of the Springfield Armory. This was a unique and perhaps independent invention, although problems with the dam height and canal depths needed to run the system led to its replacement with conventional lift locks. The other projects were typical of their era, using dams, locks, and short canals to circumvent rapids while relying primarily on river navigation. However, while most American canal projects at that time were also private, sometimes with state backing, they involved single companies with development rights on one river, such as the Western and Northern inland lock navigation companies in New York and the Potomac Company in Virginia and Maryland. The early efforts on the Connecticut lacked this central management.

Early American canals built around rapids were generally of uneven quality, and frequently proved non-remunerative. The first really successful control of navigation and commerce on an American river, with stong influences on the Connecticut River Company, was on the Merrimack River in Massachusetts and New Hampshire. The Middlesex Company, chartered in 1793, had two generations of able managers and engineers. Combining towpath canal and river navigation, it opened the Middlesex Canal between Middlesex (later Lowell) on the Merrimack and the Mystic River north of Boston in 1804, and by c1815 built or upgraded a series of short lock-and-dam projects around rapids on the upper Merrimack. Some of the latter works were begun in the 1790s as smaller, individual operations, which did not function effectively as a system until controlled by the Middlesex Company. The firm's navigation between Concord and Boston operated successfully until fatally challenged by railroads c1835-43 (Meader 1869: 183-4, 208; Shaw 1990: 11-15). The second manager of the Middlesex Company, John L. Sullivan, developed the upper river works and applied some early steamboat technology to Merrimack navigation. As discussed in section III, he saw analogous possibilities on the Connecticut River. In 1818, he began limited steamer service and secured a charter for the Proprietors of Enfield Locks and Channels (Connecticut General Assembly 1789-1836,I: 507-10).

Depressed economic conditions probably hampered Sullivan's plans for the rapids, which remained unfulfilled until his charter expired in 1823. By this time, better economic conditions, in a different regional trading context of cities competing for domestic markets, made Hartford merchants much more interested in improving river navigation as far north as possible. Excited by the technical and mercantile possibilities of overland canals suggested by New York State's great projects, New Haven merchants led by James Hillhouse conceived a plan to outflank Hartford's grip on river trade by building a 78-mile canal from New Haven to Northampton. Securing support along the route in both states, they obtained the necessary charters in 1822 and 1823. Construction of the Connecticut section began in 1825, and was finished in 1828; another seven years were needed to reach Northampton. The difficulties in design, operation, and maintenance of the New Haven and Northampton Canal, with its sixty locks and 520 feet of cumulative rise and fall, are well known (e.g., Kirkland 1948,I: 70-5; Raber and Clouette 1985; Shaw 1990: 52-5). That it succeeded too little and too late to face railroad competition in the 1840s is less important here than its effects on Enfield Canal planning.

Alarmed by any possibility of New Haven's success in their traditional arena, Hartford merchants in early 1824 planned a very broad-based set of improvements and ventures for the river to the north. In May of that year, they obtained a state charter for the Connecticut River Company. Most of the men involved had developed important positions in the by-then diminished West Indies trade, and were diversifying into new transportation and mercantile ventures. Of the company's early officers, men in this category included directors David Porter, Daniel Buck, and William Imlay. Director George Beach dealt in paints and dyes, one of many local merchants who shifted into wholesale manufactured goods. Imlay, one of Hartford's wealthiest men at this time, dealt in paints and dyes also, along with extensive contracts in grain and flour, having started his career in West Indian trading. Director Thomas K. Brace owned a line of packet boats running between Hartford and Boston. President Alfred Smith was unusual in this group, but critical: he was a lawyer who at various times served as a county court judge and a Hartford representative in the State Assembly (Talcott 1886; Erving 1925: 171-2, 211).

The influence of this group explains the power of their charter and some of its later amendments. The company's objectives, mandate, and responsibilities resembled John L. Sullivan's, but were even more sweeping, including rights:

> ...to dig, cleanse and remove obstructions from the channels and bars of said river, from and above the bridge at Hartford to Springfield...
>
> ...to lock the falls at Enfield...and to make channels to aid them, and to construct a canal on either bank of said river, near said falls, and to construct a dam or dams for the purpose of entering and leaving the locks in still water, provided the extension and form thereof shall be such as shall not prevent the convenient passage of boats and lumber down the river, nor obstruct the passage of fish; and said corporation shall have right to procure and possess any steamboat or boats, which they may judge necessary to increase commerce on said river.
>
> ...to purchase and hold the stock of the several incorporated lock and canal companies upon Connecticut river, or such part of them, or any of them, as they may judge expedient.
>
> ...[to] purchase and hold such mill or mill seat or manufactories upon or adjacent to Enfield falls as they may judge expedient (Connecticut General Assembly 1789-1836,I: 73-75).

Of the five parts to this chartered plan (channels, Enfield canal, steamboats, upriver canals, and manufacturing), the company never pursued the first, built the canal and dam, attempted steamboat freight handling unsuccessfully (section III above), was unable to obtain the other canals, and eventually developed mill seats which became the basis for the company's financial health and Windsor Locks' development (sections V-VII). We discuss the design, construction, and operation of the canal in detail in section V.

The charter gave the company advantages and constraints common to the state-chartered private ventures which characterized contemporary canal projects in New England and in New Jersey, including rights to collect tolls and a form of eminent domain to pursue its construction projects. As with similar chartered ventures in Connecticut and some other states, an appointed three-man commission oversaw the company's construction projects and assessed the damages the company had to pay for land or water taken during canal development.[1] The commissioners also had the authority to authorize additional improvements to the initial canal works, an arrangement which later allowed the company to make significant changes for waterpower canal operations (section V).

As we saw in section III, company directors considered the possibility of running a railroad instead of a canal. Although they rejected this idea and never tried to alter their charter for rail construction, their influence would probably have been sufficient to achieve this radical re-direction. By early 1825, they realized that their chartered capital stock limit of $500,000 might not be enough to accomplish all their objectives, and that more aggressive means would be required to increase the $18,000 actually raised during the company's first year. Arguing the great public benefits to be derived from their work, they returned to the legislature and secured an important charter amendment in May 1825 which forever exempted company "..stock, property and income..." from taxation, and which set up the

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[1] The state could not, of course, regulate projects outside Connecticut, and separate charters from other river states were needed to address the company's upriver ambitions.

Connecticut River Banking Company as a means of better financing the Connecticut River Company. River company shareholders could invest share for share in the bank, whose profits were also tax-exempt until the river company earned a 6% return. The Connecticut River Company could not initially establish the bank until $200,000 were expended on the navigation improvements, but the directors succeeded in halving this requirement in a second charter amendment of May 1828 (Connecticut General Assembly 1789-1836,I: 78-83). The bank invested in Connecticut River Company stock in 1829 as the Enfield Canal neared completion, but soon became less associated with the river company as profits from canal navigation failed to materialize (Erving 1925: 67-70, 173-4; Kirkland 1948,I: 70-5; see section V.C).

Connecticut River Company directors devoted much effort to promoting their program above Enfield Rapids, holding meetings and proclaiming their resolve to open navigation to the uppermost Connecticut River as well as to Lake Memphremagog, which drains into the St. Lawrence from its elongated position astride the Vermont/Quebec border. The potential to tap Canadian markets and inhibit Canadian capture of northern New England products helped galvanize support from upriver merchants and legislatures, and from the federal government which in 1825 paid for some survey work (section V.A). The 1826 voyage of the *Barnet* was part of the company's promotion (section III.C). Only Vermont actually chartered the Connecticut River Company outside Connecticut, in May 1825, contingent upon acceptance of the corporation by the other river states. Connecticut's legislature was the only other one to confirm the Vermont act, which called for navigational improvements between Hartford and Barnet. Other proposed work included a canal from the river to Lake Champlain, and from Barnet to Memphremagog, with the latter effort chartered as a separate Vermont company in 1829, the Connecticut River Canal Company. We have not determined the linkages between the Connecticut River Company and all the Vermont plans (Anonymous 1829; U.S. Army 1872: 844-5; Hayes 1917: 78-9).

The Enfield Canal, opened in November 1829, was the last upriver navigational improvement actually completed, and the only engineering work of consequence built or organized by the Connecticut River Company. The full story of the company's lack of progress above the rapids remains to be researched. We have noted the failure of the company's steam-tow operations between upriver canals (III.C above). Other factors probably included insufficient capital to purchase or rebuild the older upriver canals, and the opposition of Massachusetts interests fearful of losing trade between the river and Boston. The company
made little money from tolls, but after 1845 began to profit from sale of waterpower (section V). By this time, railroad construction and larger scows made the canal increasingly obsolete for navigation. When Massachusetts river interests tried to revive river navigation after the Civil War to cut rail freight costs, they found that the Connecticut River Company's change in mission now made it an opponent of any plans which might affect its diversion of water for power. For Connecticut River navigation, the most ambitious proponent in the river's history became one of the most vigorous opponents.

B. Downriver Channel Improvements Before the Civil War

Hartford is located at the upper end of natural river channels available, at times, to vessels drawing more than about two feet. For over 200 years, Hartford merchants and shippers worked to maintain larger navigable channels downriver, and to restrict the size of channels to the north, so as to maximize their role in transhipment. They wanted to make Hartford, rather than Warehouse Point, the upriver-downriver junction. By building bridges and selectively promoting channel improvements, they succeeded.

Limited, local channel improvements began in the late 17th century, between Hartford and Wethersfield. As the West Indies trade increased in the 18th century, mercantile demands for more extensive river work grew. Sand bars inhibited Hartford's trade position relative to Middletown's in this era, because of sand bars which limited ship movement above the latter town. Proposals for toll-funded improvements between the two competing river ports, beginning in 1764, foundered on opposition from shippers, especially those using vessels under fifteen tons. By 1790, however, the combined effects of increased trade prospects, much faster upriver settlement, and the appearance of larger vessels led to renewed efforts to secure state-chartered rights to open river channels, including those above Hartford. The earliest attempt to clear the shoals to the north dates to a 1791 legislative grant to Roger Newbury, John Reynolds, for a lottery-supported project. Nothing came of this proposal; Reynolds did somewhat better with his 1798 bridge project discussed in section III.D (Love 1903: 404-5). The first -- and only -- successful ant-ebellum channel improvement below Enfield Rapids began in 1800, when Hartford merchants John Morgan and John Caldwell spearheaded the state-chartered Union Company to deepen the channel and stabilize the banks between Hartford and Middletown. By 1806, the Union Company added about two feet of channel depth and began collecting tolls; this work speeded the demise of Middletown's port when the regional economy soon worsened (ibid: 397-400; Talcott 1886: 657-8; Allis 1939: 137-46).

Although the Connecticut River Company was chartered to improve the channel between Hartford and the rapids, the failure of the company's steamboat ventures and its limited toll income probably stifled any further drive for channel work below the rapids until the end of the Civil War. River shipping interests were by then largely limited to operations below Hartford, and were competitive with rail freight into the city from the south or west. Neither the shipping or canal interests saw much to gain from proposals to push navigation further north.

C. Unfulfilled Navigation Plans from Hartford to Holyoke, c1870-1950

By 1867, congressional representatives from Connecticut and Massachusetts turned to the Army Corps of Engineers to further their constituent's conflicting navigational aims, in the absence of any possible new private ventures. Corps engineers quickly assessed the situation, and recommended concentrating efforts on the river below Hartford, which was navigable and commercially active. The Corps began dredging the channel below Hartford in 1870, creating a passage 8 feet deep and 100 feet wide at low water by 1872 (Love 1903: 400). The river above Hartford was effectively blocked by the dam at Holy-oke, and, while readily navigable between this dam and Enfield Rapids,

was nearly closed by the rapids, the small canal around them, and the shoals above Hartford. The shoals or sand bars often created channels less than 1.5 feet deep, possibly representing a post-1830 worsening of conditions following upriver dam construction and riparian development (section II). Despite these limitations, Massachusetts interests secured appropriations in 1870 and 1872, with which the Corps studied possible improvements above Hartford and temporized with the shoals by building about seven small, brush-and-stone wing dams before 1881. The wing dams were intended to concentrate low water on the bars, force high water onto the bars to scour more channels, and accumulate tidally-moved material which might otherwise aggravate bar conditions. Difficult to maintain, the wing dams proved an obstacle to navigation, and aggravated ice build-up and backwater at Windsor Locks mills (Porter 1885: 50; see section VI.A). By 1915, the Corps removed most or all of the dams, erasing what proved to be the only substantive attempts to improve navigation between Hartford and Holyoke after 1830 (U.S. Army 1870: 74-5; 1871: 84-5, 761-7; 1872: 82; 1879: 56; 1880: 75; 1914,I: 146).

Corps engineers always saw the wing dams as temporary and incomplete improvements, since no channel improvements above Hartford had much value unless the rapids were navigable. Plans to accomplish this latter end seemed so costly and improbable that in 1875 the Chief of Engineers recommended using remaining appropriations at the *mouth* of the river (U.S. Army 1875: 110). With hindsight, this seems a very practical suggestion. The Corps made detailed plans or surveys for Enfield Rapid improvements in 1871-74, 1897, 1904, 1930, 1939, and 1949. None were built, and we will not summarize them all here (U.S. Army 1872: 836-60; 1873: 1004-6; 1874,II: 249 ff.; 1898: 976-88; 1905: 902-52; 1930,I: 127-28; Leuchtenberg 1953: 14-19, 146-57, 235-9). While all included river navigation alternatives with one or more locks and dams, the earliest plans favored a new, much larger canal along the east side of the river from the head of the rapids to the Hockanum River in East Hartford. This preference reflected contemporary engineering uneasiness with large-scale river lock projects, which remained an undeveloped idea in the United States until the Corps began domesticating the Ohio River in the mid-1870s. By the late 1890s, with two decades of new experience, Corps confidence in river conquest was embodied by Major Smith S. Leach in his report on the Enfield Rapids problem:

> ...the proposed plan for making the river itself navigable avoids some objections to a lateral canal. It may be urged against lateral canals generally that they substitute at all seasons an artificial and restricted channel for a natural and less restricted one. A canal..is..more difficult to navigate than a [comparable] cut in the bed of a river. The possible speed is less in the canal...In cold climates the canal is closed by ice sooner than the river, and opens later. There is a probability of suspensions of navigation in a canal by accidents to the trunk, which is not the case in a natural channel...A river navigation makes it possible to reach every point on both banks, and serves the entire district to the which the river is tributary (U.S. Army 1898: 985-6).

Despite its ability to generate plans, the Corps never conflated feasibility with cost-effectiveness. Until 1939, none of the Corps' Enfield Rapids proposals explicitly included hydroelectric power generation as a potential benefit of government construction. When measured in terms of construction costs *vs* possible bulk freight cost cuts for Springfield, Chicopee, and Holyoke, the navigation projects were readily opposed by Connecticut interests. The Connecticut River Company was really more concerned with potential interference with its power system, although the Corps generally argued such problems would not occur. In addition to the Massachusetts and Connecticut sides of the navigation arguments which formed every debate over the rapids after 1870, reaction to any Corps plans here after 1905 were also influenced by assessments or competing proposals for private hydroelectric generation (see section V.E). The Corps learned to extricate itself from dense forests of argument by insisting that the states or municipalities involved adjust all of the many bridges to navigational requirements and build terminals, and (except in 1939) that private interests finance dam and powerhouse construction in return for use of the water at the rapids. Congress rejected the 1939 plan, and a stalemate of river interests effectively rejected all the others. The rapids today are less navigable than they were in 1830, when small vessels could use the longest canal on the Connecticut River.

V. PLANNING, CONSTRUCTION, AND HISTORY OF THE WINDSOR LOCKS CANAL, 1824-1991

A. Planning and Design, 1824-1827

Available information on the Connecticut River Company's early plans for its canal is incomplete, but the chronology and results of these plans emerge clearly in our sources. For about nine months after its May 1824 chartering, the company's efforts were oriented primarily towards generating interest in its upriver navigation strategy. In February 1825, President Alfred Smith successfully secured Federal assistance for surveys of improvements needed to link Lake Memphremagog and Long Island Sound, and in May became Connecticut's commissioner to cooperate with these surveys made under War Department auspices. By this time, the company had also retained an engineer to survey a route around Enfield Falls and estimate potential engineering costs. To assess potential waterpower development, board members David Porter and William Ely examined potential mill sites on both sides of the river along the possible canal routes (Erving 1925: 59). Based on these and related estimates of expected damage payments, the Connecticut River Company realized that its authorized capital stock would be insufficient to complete even its work at the falls, and in May 1825 petitioned the General Assembly to create the Connecticut River Banking Company (Connecticut River Company 1826: 2-3; see section IV.A above).

On the upper Connecticut River with the federally-sponsored engineers and surveyors, Alfred Smith accompanied a reconnaissance of two possible canal routes from Barnet, Vermont to Lake Memphremagog. By the end of May 1825, he realized that this survey could not complete work to Long Island Sound in one season. Not wishing to lose most of a year, the Connecticut River Company then retained a large engineering team of its own to survey routes and estimate costs for improvements from Barnet to Hartford. This work began with a re-survey of the Enfield Falls area, and included estimates of work needed on the existing upriver canals, which the company hoped to purchase. There were, then, at least two surveys of the falls made in 1825 (ibid). The company board probably chose the basic route in early 1826. Promoting the enterprise, raising the capital, and assessing the potential of a railroad delayed the start of construction until about June 1827 (Lanati 1976: 3). No additional surveys were apparently made until the May 1827 lay-out of the selected route.

Canal surveys required use of wye or other leveling instruments, targets or rods, compasses, and measuring chains to determine the levels, angles, curves, and distances of possible canal routes. Survey parties consisted of six to ten men, including axemen to clear lines of sight and set pegs and stakes (Fitzsimons, ed. 1971: 24-33). There were few engineers of any training or experience available for American canal design in the mid-1820s, and New York State's epochal 1817-25 construction program created a small corps of men who became the nation's first group of professional consultants (e.g., Shaw 1990: 160-64). Like most private canal promoters acting in the flush of New York's projects, the Connecticut River Company relied on senior New York engineering veterans and their assistants. Demands on the time of the principal engineers, often hurrying between projects in several states, meant that much survey, lay-out, and superintendency work was delegated to younger assistants.

The Connecticut River Company retained two chief engineers at different times, Holmes Hutchinson (1794-1865) and Canvass White (1790-1834). Hutchinson worked as engineer and chief engineer on the New York State canal system from 1819 to 1841, during which time he also worked on the Blackstone Canal in Rhode Island and Massachusetts (built 1824-28) and surveyed the Cumberland and Oxford Canal in Maine in 1825. He later became involved with several New York State railroads. White became chief assistant engineer on the Erie Canal, and developed hydraulic cement on that project before becoming a consultant on other canals in 1823. He became especially active in Pennsylvania, serving as chief engineer on the Union Canal (1824-26) and the Lehigh Canal (1827-1834), and as a consultant for the Schuylkill Navigation Company in the late 1820s. He also worked on the Delaware and Chesapeake Canal between those two bays, and was chief engineer on the Delaware and Raritan Canal in New Jersey from 1825 until his death (Whitford 1906: 1157, 1170). Available Connecticut River Company records on Hutchinson's and White's work are very limited, but it appears that White was retained by early 1825, made the first surveys for the company around Enfield Falls, and returned in 1827 to lay out the final route. The company hired Hutchinson to make the 219-mile survey from Barnet to Hartford in 1825, with much of the work probably performed by an assistant engineer, two surveyors, and about thirteen other assistants (Connecticut River Company 1826: 2-3).

The engineers faced several basic problems in working around the falls. The Connecticut River had to be sufficiently dammed to direct water into the canal, and to allow for boat traffic in reasonably calm water. Immediately below the dam, water had to be let constantly into the canal to maintain desired water levels and lock impoundments during non-winter months, while at the same time boats had to enter or exit the canal, moving with or against the flow. At or near the upper end of the canal, defences against river flood waters were needed. The difference in elevations between the upper and lower end of the rapids had to be bridged with lift locks. Finally, a volume of water had to be carried between the canal intake and any points of lockage, with a relatively level surface and a cross-section adequate for boat traffic. The water volume had to go over or across any tributary streams, and be retained by banks which would hold water, retard erosion anticipated by steamboat traffic, and resist floods. All solutions, ideally, minimized construction costs and maximized potential waterpower use of the canal.

We have not located any of White's surveys, although a detailed map approved by the canal commissioners in June 1827 shows the canal as first built and must reflect his work (Barnard 1827). Hutchinson's 1825 report included three alternative plans with estimated cost projections for the Enfield Canal (Connecticut River Company 1826: 26-31). None of these plans match the final design, for which White must be credited, but they included the basic elements of the canal as built:

an upper canal entrance of a dam with an adjoining boat-protecting pier, a headgate structure, and a guardlock to pass boats between canal and river;

canal prism (water-retaining embankments) of fill placed on the rocky river bed, or of earth excavated or filled along existing river banks;

three 10-foot lift locks at the lower end of the canal, making up most of the fall in the rapids.

Placing the lift locks at the south end avoided deep excavations through higher surfaces to the north as well as construction of an additional guardlock at the lower end of the canal, and retained most of the fall in the river for potential waterpower use.

Two of Hutchinson's plans called for a dam across the river, a quarter mile below King's Island, high enough to raise the water some 22 feet to the upper level of the rapids. The proposed canal lengths of these two plans, on either side of the river, were shorter and required less excavation and embankment work than the third route beginning at the head of rapids. Dam construction across the river may have appeared more formidable to the company than the more expensive route from the head of rapids, which Hutchinson estimated would cost about $119,000 but would require only a shorter wing dam from the west bank. White's final design followed the longer route with a wing dam, but was more structurally conservative than Hutchinson's plan, which called for use of the rock-bound river channel west of King's Island as part of the canal. Hutchinson would have avoided crossing Stony Brook, but would have also built more river-bed embankment further out in the main channel, and subjected the canal to floods from the brook. We have no information on why a canal on the east side of the river was finally rejected, although of Hutchinson's two cross-river dam plans, the east side canal was longer and cost more (about $89,000 vs. about $81,000 on the west side). The presence on the east side of more large streams requiring crossings, and more developed commercial or industrial property requiring greater damage settlements, may have been important factors. Company board members may have also found less potential area for waterpower development.

B. Original Construction and Features, 1827-29

1. Building the Canal

The Connecticut River Company began the construction process in May 1827, with solicitation of proposals from contractors and final location of canal features by Canvass White. We know nothing of most of the contractors. Standard practice in this period involved construction contracts of approximately one-mile segments, with costs based on estimated amounts and types of material to be excavated, moved, or erected. In this framework, there would have been only some four to six contractors for Enfield Canal prism segments, plus other builders of the dam, headworks, aqueduct, locks, and a few other engineering structures. Local farmers could have taken some of the basic contracts, although by this period veteran Erie Canal contractors also traveled among new canals. Many such entrepreneurs were Irish immigrants, and the documented presence of Irish laborers on the Enfield Canal suggests that Irish contractors may have led such groups to Connecticut. Consulting engineers from New York sometimes brought in experienced contractors (Shaw 1990: 164-65). Local artisans sometimes built masonry canal engineering structures in this period. On the Enfield Canal, Vermont native Joseph Parker is credited with construction of the locks (Lanati 1976: 10).

Canvass White evidently supervised final lay-out of the canal, and probably explained the work to contractors, company board members, and the state's canal commissioners (ibid: 3). Teenager Jabez Hayden, a Windsor native then visiting relatives in Pine Meadow, followed this process with interest and later described the trial-and-error methods used to estimate some earthworks:

> ...some gentlemen in charge with their engineer came on the ground to decide what should be the slope, the angle of the inside of the canal necessary to prevent the new bank from sliding in when the water should be let in...They went over the river bank and selected a spot where the Dexter paper mill now stands, then they graded off the bank until they obtained what they thought a suitable pitch or grade. When [sic] the man of the shovel raised a laugh by exclaiming "if they will make it as good as that I'll compounce it good." The engineer made a note of the angle of the slope decided upon for future reference (Hayden 1900: 29).

Hayden probably observed an empirical exercise which assessed the repose angles of existing soils, but could not have closely defined most canal prism as built. As discussed below, nearly all the eastern canal embankments were higher than the original river banks or river bed, requiring entirely artificial earth, stone, and timber structures. Supervising engineers and contractors most likely determined the final dimensions of these structures, perhaps with occasional visits from White during the approximately twenty-seven months of construction. There is no evidence of White's continued presence here, and he worked on much larger projects in New Jersey and Pennsylvania in this same period.

Edwin A. Douglas (1804-59; sometimes spelled Douglass) has been credited with being superintendent or chief supervising engineer for Enfield Canal construction (Coffin 1967: 10), a claim which while as-yet undocumented is probably correct. A native of Stephentown, NY east of Albany, Douglas was perhaps the most important protege of Canvass White, working with him on the Erie Canal and White's later projects, and assuming some of his responsibilities upon White's death in 1834. While working on the Enfield Canal, he met the family of Seth Dexter (1776-1841), one of Pine Meadow's early industrial entrepreneurs, and later married Dexter's daughter Harriet in 1834 (Stiles 1892, II: 173). His somewhat absentee partnership with brother-in-law C.H. Dexter (1810-69) in the latter's paper mill was an early boost to what became Windsor Locks' most enduring paper-making firm. Douglas probably left Connecticut soon after completion of the Enfield Canal, and in 1831 served as supervising engineer of the Delaware and Raritan Canal's western section and lower feeder under White's direction. Douglas became superintendent and engineer of the Lehigh Coal and Navigation Company (1835-59), and a founding director of the Thomas Iron Company at Easton, PA in 1854. Working with Lehigh Navigation co-founder Josiah White, Douglas designed the then-highest American lift locks for the upper Lehigh Canal. He also supervised establishment of the first American wire rope factory for Lehigh Navigation, at which John Roebling made rope for the company's first great inclined planes at Mauch Chunk, PA in 1848 (Henry 1860: 393-4; Hartman 1938: 73; Madeira 1941: 30; Morton 1946: 204-5; Foulke and Foulke 1979: 29; Sayenga 1981; Shaw 1990: 88, 164).

Douglas and the Enfield Canal contractors supervised a largely Irish work force which grew to at least 400 men (Lanati 1976: 3). Competition for canal laborers in the northern United States was intense during this period (e.g., Kalata 1983: 95), and the men who came to work along the Connecticut River must have received at least the average wages for such work prevailing elsewhere: about $12-14/month for six-day work weeks (Shaw 1990: 167-68). There were relatively few kinds of mechanical construction equipment available at this time, other than animal-powered tree-stump pullers and hand- or animal-powered cranes, leaving most work done with spades, wheelborrows, or animal-drawn plows, sleds, scrapers, and scoops. We

have little information on Enfield Canal construction practices. On the short sections where both banks could be built over existing slopes to relatively low heights, animal-drawn equipment may have allowed for rapid progress: three men and a horse or ox team could sometimes excavate a mile of Erie Canal in a season (Shaw 1966: 93). Most Enfield Canal sections were far more formidable, however. In addition to setting embankment footings along several miles of riverbed, the Irish built up the generally high eastern canal banks with thousands of arduous wheelbarrow loads, pushed along single-plank runways from the western banks (Hayden 1900: 30, 33-34). The extensive use of sandstone rubble on the canal banks, discussed below, may have involved cranes.

The construction of much high embankment directly on the riverbed or on low floodplain near the lift locks appears to have made this short canal particularly difficult to build. Much of the embankment north of the later railroad crossing washed out during construction, along with hundreds of wheelbarrows, and had to be re-done (Hayden 1900: 30; Abbe 1897: 571). A rough preliminary comparison suggests that the Enfield Canal may have required over twice as much labor per mile as parts of the Erie Canal, which avoided construction in rivers for anything other than dams or river crossings.[1] Enfield Canal costs, totaling about $200,000, reflected these conditions. Despite its relative lack of locks, large aqueducts, or other masonry structures, the per-mile cost of about $36,400 was up to three times that of some contemporary canals.[2] We estimate about half the costs were for the laborers. The river embankments compounded the usual dangers of canal construction, which killed at least one worker on the Enfield Canal and first brought Catholic priests to the area to administer last rites (Anonymous 1954).

Relatively few of the nameless Irish workers, who lived near their work in temporary board houses or shanties, stayed after the canal opened in November 1829 (Hayden 1900: 34). Their principal legacy is their work, which while modified survives with much integrity of form and material. Most local Yankees had never before met any Irish, and the impoverished energy of the laborers left impressions which resonated in memories two generations later:

> The came on rafts and in scow-boats, often with their entire worldly goods knotted up in a red bandanna, and many with not even that. They camped in the woods and cooked their food in the huge caldrons used for melting tar (Abbe 1897: 271).

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[1] On the 94-mile middle section of the Erie Canal, about 1000 men worked in 1817, and about 2500 worked in 1818 and 1819. This section was completed by July 1820 (Shaw 1966: 87-98). Assuming the 1820 workforce was similar to that of 1818-1819, and that July marked an approximate mid-point in a construction season, the middle section required about 7250 man-seasons or 77 man-seasons per mile. Assuming seasons of comparable length (perhaps unlikely given Connecticut River conditions), if 400 men worked for about 2.5 seasons on the Enfield Canal, the comparable result is 182 man-seasons per mile.

[2] Approximate per-mile dollar costs of contemporary canals, in thousands, include 19.7 for the Erie, 20.6 for the Morris in New Jersey, 26.7 for the Delaware and Raritan, 12.2 for the Blackstone (a project which minimized prism construction in favor of more slackwater navigation), and 25.6 for the Enfield's ill-fated competitor from New Haven to Northampton (Shaw 1990).

2. Engineering Features

Given the choice of the west bank, Canvass White's general solutions to the problems outlined above were simple and effective, and generally remained viable even after the Connecticut River Company's principal objectives shifted from navigation to sale of waterpower. His design is perhaps best outlined in a description of the canal as constructed. There were, broadly, two classes of original Enfield Canal features: masonry and timber structures which dammed, directed, manipulated, or carried water; and earth, stone, and timber embankments which simply retained water.

a. Masonry and Timber Engineering Features

The June 1827 map of the canal shows a proposed wing dam from each side of the river at the head of the rapids, leaving an opening in the river about 70 feet wide. The east wing dam was supposed to be only 1 foot high, probably to slow the current for boats using the canal while providing limited additional passage for fish and open-river navigation (Barnard 1827). The east wing dam was not built during initial construction, perhaps reflecting concerns of other river interests; the original river impoundment and canal headworks was built from the west bank. A stone-filled timber wing dam, about 400 feet long and 3-5 feet high, angled upstream into the middle of the river from a 200-foot-long pier of similar construction which ran parallel to the west bank (see Figure 2). The pier was about 100 feet from the bank, and formed a protective channel or basin for boat traffic. At the lower end of the basin, the canal intakes consisted of a 70-foot-long stone headgate structure extending west from the dam, probably with thirteen brick arch gate openings and wooden, wheel-operated gates, and a stone guardlock between the west end of the headgates and the river bank. The guardlock was about 86.5 feet long between gates and 19.5 feet wide, and allowed boats to move in or out of the canal, bridging the difference of several feet between the river and upper canal levels, while the canal level was maintained by the headgates. Headgate and guardlock structures rose 16 feet above original canal levels as a bulwark against flooding. The ashlar masonry of these features was random-coursed sandstone or arkose, set in hydraulic cement originally or during repairs several decades later; the aqueduct piers and lock flight described below were similarly constructed. Despite Canvass White's fame in the development of hydraulic cement, it is not known if the Connecticut River Company spent the money for this important material during initial construction; high cost factors discussed above may have inhibited the company's zeal. Stone for these structures, as well as for canal embankment facing or lining, was readily available along the north third of the canal route; some of the present quarries were probably first opened for this purpose (Connecticut River Company 1855-56; Porter 1885: 48-9; U.S. Army 1905: 934; Lanati 1976: 4; C.T. Main 1978).

Combination guardlock and headgate structures are rare among American canals, and Hutchinson's 1825 estimate did not evidently call for this arrangement. The use of both types of structures usually marked an attempt to combine navigation and waterpower use; examples of combined systems with similar arrangements include the one built 1822-48 at Lowell, MA and the Dundee Canal built 1858-61 on New Jersey's Passaic River (Malone 1983; Raber 1986).

Most of the 5.5-mile canal route below the guardlock ran along steep banks 10 to 30 feet above the river. Below the bottom of the rapids, a narrow band of floodplain less than 200 feet wide paralleled the higher bank to the west. The 1827 floodplain elevation is not recorded in documentary sources, but represented the lowest land surface along the route. Canvass White ended the canal in the floodplain with the flight of three masonry locks, each about 88 by 19 feet between gates, with 16-foot-high walls. Two oblong, stone-lined basins, each about 220 by 60 feet, accommodated passing boats, and may represent a lengthening of the descent to conform to a natural slope in the floodplain. The flight of locks made up most of the descent around the rapids, but left about 3.3-4.5 feet of fall in the upper four or so miles of canal: although usually described as having 10 feet of lift each, the three locks did not create equal drops, totalling instead about 25 feet. The bottom of the uppermost lock (No. 1) is only about 6 feet below the adjacent prism bottom, as is apparent from recent drawn profiles, and from comparisons of lock bottom elevations with canal bottom elevations surveyed in 1988 (Porter 1885: 47-9; U.S. Army 1905: 936; Colton 1960, 1965; C E Maguire 1987; Raber 1989).

There were few special engineering features between the upper and lower end of the canal. One or more set of stopgates, built about 3500-4500 feet below the headgates, was installed to raise water in the upper canal about 5 feet to equalize pressure on the headgates during high river water. The stopgates, probably made of timber with masonry piers, may have been added sometime after original construction. One set was reported removed by 1880, while another was seen in the early 20th century. Their design remains undocumented, though fragmentary masonry remains from one pier survive (Figure 2). To carry the canal over Stony Brook in Suffield, the only stream of any great breadth on the route, White designed a trapezoidal timber aqueduct on six masonry piers or abutments. This structure was originally about 100 feet long and 60 feet wide at the top, with the trapezoidal cross-section about 10 feet high with sides angled at 45 degrees. Similar in design to many contemporary structures on other canals, the aqueduct probably had a closely parallel towpath bridge for horses or mules on the downstream side. Most smaller streams crossing the line of the canal were simply intercepted by construction of high east canal banks. The village at Pine Meadow had somewhat larger Connecticut River tributaries, some of which were used for pre-1827 mills, requiring several canal structures. An otherwise undocumented waste wier appears opposite the junction of Main and Suffield streets on the 1827 map, where two short unnamed streams with wide mouths converged on the canal. If built, the waste wier was probably a masonry passageway through the east canal bank, with a wooden gate. The canal company did build a culvert to pass Kettle Brook under the canal below the Dexter and Haskell saw and grist mills, and a flume to the south to run Adds Brook water to the c1811 Haskell distillery, where the mill pond was removed by canal construction (Barnard 1827; Connecticut River Company 1855; Porter 1885: 49; Hayden 1900: 32-3; U.S. Army 1905: 936-7).

By moving present Main Street entirely west of the canal, from its previously more winding route, the company and the canal commissioners precluded the need for much bridge construction in Pine Meadow. Proximity to the river put the canal east of virtually all property lines in Suffield, and limited landowner access problems in most Windsor areas. The 1827 map suggests the company had to erect crossings to the ferry opposite Warehouse Point, and near the Haskell

distillery to accommodate the mill's owners. These bridges were probably trussed timber structures with masonry abutments. Owners of adjoining properties built later bridges, probably at their own expense, as industrial or transportation projects developed. The earliest such crossing was probably for the re-built Enfield Bridge, resurrected on its original piers in 1832. Finally, the canal company built a house near each end of the canal for locktenders, probably in 1830 when a locktender/toll collector was appointed (Barnard 1827; Connecticut River Company 1855-69; Erving 1925: 149).

b. Prism Construction

The original canal prism, or water-retaining embankments, represented the largest component of Enfield Canal construction. Prism dimensions varied, with widths at the top ranging from 44 to 160 feet; except in the center of Windsor Locks, the canal in most places is about 80 feet wide. The narrower, approximately 50-foot width through former Pine Meadow may reflect a conscious attempt to minimize impacts on the small village and maximize space for anticipated industry. In other places, prism dimensions and form appear to have followed more from terrain and local availability of desired building material (Porter 1885: 49).

All accounts of original construction emphasize it was done by hand, with shovel and wheelbarrow, which suggests that the Irish laborers moved any excavated or fill material over the shortest possible distances. The most economical means of prism construction with such methods was cutting and filling along gradually-sloping terrain parallel to the canal route. The excavated material could be piled up to form an artificial embankment opposite the top of the original slope, whose reshaped form became the other canal bank. Terrain along the Enfield Canal route made this approach impossible in many places, because the river banks were too steep and/or rocky. The river valley in this area is underlain by Portland arkose, which was at or near the surface along most of the uppermost 3.2 miles of canal route. Except for a small stretch of floodplain south of Stony Brook where cut-and-fill construction was possible, workers had to build an artificial bank on the rocky bed of the river in this upper section, using the original river bank as part of the western side of the canal. For riverbed construction, the builders evidently fit stone-filled timber crib foundations to the bedrock, bolted and/or sunk the foundations in place, and erected framework above to receive the earth dumped from the long, narrow wheelbarrow runs. Since the bottom of the canal here was thus below river water levels, and the top of the embankment had to remain relatively level, the embankment became taller as it followed the descending river, reaching a height of about 25 feet around the later railroad bridge over the canal. From the railroad bridge south, the river banks consisted largely of late glacial terrace or lake deposits, with occasional areas of till and alluvium. Prism construction methods over the last two miles of the canal involved cut-and-fill methods along any slopes with sufficiently gradual, high surfaces, or introductio of new fill where slopes were too steep or low. The eastern side, at least 10 feet wide at the top, served as the towpath (Barnard 1827; Connecticut River Company 1855; Hayden 1900: 30; U.S. Department of Agriculture 1958; Schnabel and Erie 1964; Colton 1960, 1965; Lanati 1976; Raber 1989).

No original specifications for prism dimensions appear to have survived, and repeated repairs and modifications make description of original conditions difficult. The necessarily opportunistic nature of prism construction created a variety of forms, in which the principal factor was holding water at a desired elevation with the minimum required depth and width. The minimum depth was probably about 4.5 feet, but ranged up to 20 feet in sections with very high embankments; average depths were probably 5-12 feet. Water surface widths probably averaged about 75-80 feet except in the later-developed section of Windsor Locks, where the width is about 50 feet. Exterior embankment wall slopes generally followed from fill material angles of repose. Interior slopes vary today from vertical, in the center of Windsor Locks and some other places to the south, to about 33%. The latter slope was considered typical in recent decades, and may represent the approximate objective of the canal builders for places where original surfaces were high enough to allow for relatively low embankments (U.S. Army 1871: 764, 1872: 843, 1905: 935; Harte 1938; Lanati 1976; C E Maguire 1987; Whitman & Howard, Inc., 1987; personal communication, Robert English).

The finished surfaces of the canal embankments are also incompletely documented, and have never been fully described. A 2-to-3-inch-thick clay or clay-like liner, to enhance water retention, has been noted on the bottom and sloped sides by recent canal workers, but was not mentioned in any earlier accounts. Recent archaeological investigations, and documented practice on contemporary canals, indicates that use of local alluvial soils as prism liner was maximized by canal builders. Clay or clay-like material brought from any distance was probably used only for repairs or where local soils were too porous (Raber 1989; Fitzsimons, ed. 1971: 56; personal communication, Robert English). Flat stones or rip-rap lined most or all exteriors of embankments built on the river bed. At least the upper interior prism surfaces were lined with dry-laid sandstone rubble to resist steamboat wave wash, but observation of drained canal sections suggests that such lining was often no more than 4 feet high. Hydraulic-cemented vertical walls, retaining rather than lining some sections, were of sandstone ashlar or mixed ashlar and rubble. Of undocumented but probably varying heights, these are most prominent between or around the locks, and in the center of Windsor Locks. Vertical interior walls were relatively expensive to construct, and were probably erected only where narrow canal widths were desired, or where unusual water pressure or boat damage was anticipated (Connecticut River Company 1860; Lanati 1976).

C. Pre-Railroad Era Operations, c1829-44

After the well-publicized November 1829 opening in which both of Thomas Blanchard's steamboats passed through the canal, Connecticut River Company canal operations were sluggish. Toll-paying traffic of several types was relatively constant prior to completion of the Hartford and Springfield Railroad, but was not profitable (Erving 1925: 173-74). The company was empowered to collect tolls of 75 cents per ton of lading and 17 cents per vessel on ascending boats; the lading charge dropped to 50 cents per ton on descending vessels. Tolls, the irregularity of canal operation, and the relatively small size of the locks tended to encourage continued traffic over the rapids. While the canal allowed for larger loads and, briefly, more passenger traffic, it probably did not radically alter river traffic patterns. Freight handlers undoubtedly compared canal tolls to the established costs of using the rapids, and at times probably found

little advantage in the new route.[1] The canal was never entirely reliable, either. Even when new, it was almost certainly subject to the problems of flood and ice damage, pickerel grass growth, muskrat penetration of the towpath, and deterioration of engineering structures which plagued the company during a period of better documentation beginning in 1855. Maintenance problems began almost immediately, and were probably compounded by low toll yields. By June 1830, Thomas Blanchard found it prudent to advertise in the *Springfield Republican* that his second steamboat operated even when the canal did not:

> Passengers can be sure of arriving at Hartford and Springfield at the proper hours, the steamboat *Vermont* having the power to ascend the Falls at Enfield when the canal is out of order, in equally as quick time when passing through the canal. The *Vermont* will therefore lose no time (quoted in Lanati 1976: 4).

Running up the rapids required much more wood or, later, coal fuel, which may be the only reason why any of the steamboats then operating north of Hartford would pay tolls to carry passengers. Those not too large for the locks probably by-passed the canal frequently, but at least one steamer is said to have used the canal daily for upriver passenger trips. Towing flatboats upriver may have been a more common use of steamers in the canal, as about six such towing vessels were reported running between Springfield and Hartford by 1836. Many flatboats went through the canal towed by horses, however, and at least one man living along the canal hired out horses and boys for such work until c1845 (Hayden 1900: 31-2). Steam towing sometimes involved keeping two steamers in the river, at opposite ends of the canal, and having the scows pulled through the canal by horse (Abbe 1897: 274). Despite the existence of at least one undated engraving of a flatboat being poled through the canal, we do not know how if this method was common or permissible. Extensive poling would have weakened canal embankments or bottom, and may have been proscribed. Poling was also probably slower than, at least, steam towing, which took just over an hour when the canal was fully functional (Erving 1925: 145-6).

During the first fifteen years of operation, then, one of the Connecticut River Company's major gambits -- a canal adapted to steamboats -- proved unfruitful because of market, traffic, and boat size patterns. We do not know if the company made any attempt to cut toll rates. The Hartford merchants running the company, some of whom remained on the board for thirty years, also made little profit from water rights in this period. The company sold only six water leases prior to 1845, some of which went to firms which failed, and could have made no more than $15,000 from this source during this period (Windsor Deed Books 32: 277-9, 33:274-6, 34: 288-90, 35: 278-9, and 37: 4-5, 50-2, 85-91, 148-50, 175-7). In addition to larger factors in this period such as under-development of industrial technology or management skills, and fluctuating economic conditions, limited profits from water rights probably stemmed from high lease prices and

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[1] It cost at least $13.67 to take an 18-ton load of freight up the canal, plus any costs of towing or hauling, vs. several dollars for extra swift-water men to help haul a flatboat up the rapids plus undocumented charges for hauling and transhipping several tons of excess freight around the rapids. A 40-ton load up the canal cost over $30.00. The results of such arithmetic remain uncertain, but it seems likely that flatboat traffic via Warehouse Point was competitive with the canal until the railroad arrived.

water delivery problems. After the railroad stripped the canal of most freight traffic, the Connecticut River Company "...granted several leases at greatly reduced prices..." (Hayden 1900: 33). Post-1844 canal modifications also suggest that the original canal design was more oriented towards minimum water needed for boat traffic than maximum water deliverable to mills. The company's promotional efforts at attracting industry, such as lobbying to name the new post office at Pine Meadow "Windsor Locks," were not sufficient to overcome these more fundamental problems.

D. The Heyday of Industrial Water Supply, c1845-1908

Limited commercial traffic continued on the canal until the late 19th century, especially coal delivered to riverside mills in Windsor Locks, but by the mid-1850s the Connecticut River Company's annual toll receipts of $1100-$1400 suggest that fewer than one hundred vessels passed through the canal each year (Connecticut River Company 1856-69; Stiles 1892,I: 508; Hayden 1900: 32). The directors quickly recognized that "...the resources of the Company [were] limited to the water rents and tolls connected with the mills" (Connecticut River Company 1859: 4). Lower lease prices attracted new tenants immediately after 1844, and lease receipts for water privileges and mill lots rose to about $8700-$9600 per year in the period 1855-65. Sustained lease growth was impossible without maintenance of the canal and expansion of its water supply, tasks to which the company does not appear to have regularly devoted itself until the 1855-69 tenure of C.H. Dexter as president. The most prominent local industrialist of his day, Dexter was also the only mill owner to sit on the Connecticut River Company's board prior to his death in 1869. Conscious of industrial needs and canal company balance sheets, he led a sustained maintenance and rebuilding program which allowed the company to take advantage of expanded manufacturing activity after the Civil War. By his death, annual lease revenues were about $15,000, and the company was paying regular dividends (Connecticut River Company 1856-69). His efforts transformed "...that which had been almost valueless [into] a fairly remunerative property," and assured water power to his own firm and others (Stiles 1892, I: 511).

From available Connecticut River Company annual reports (1856-69) and other, limited primary data, we can distinguish four major classes of canal maintenance and modification in this period, especially prior to c1881:

- removal of silt and pickerel grass, which accumulated in the canal's often shallow depth and slow current, using steam-powered dredges and steamboat-propelled mowing machines;

- stabilization of canal structures against the regular assault of high water and ice, involving significant re-building/enlarging of embankments and aqueduct piers and wing walls, as well as in-kind repair of damaged features;

- replacement and upgrading of operating equipment such as headgates and lock gates;

- controlling greater volumes of water using enlarged dam structures, a wider aqueduct, limited canal deepening, and new overfall or drain facilities to remove high water.

Dredging, mowing, and stabilization required regular attention and often absorbed much of the company's operating funds, but by the end

of Dexter's life these problems were well under control, with the riverbed-supported towpath in Suffield almost entirely rebuilt. The more expensive structural changes needed for increased water delivery appeared more slowly, delayed by maintenance demands, and were ultimately limited by legal constraints on dam elevation. In 1849, state commissioners overseeing the canal allowed the company to build a 461-foot cribwork wing dam from the east bank of the river opposite the original dam, leaving a 100-foot gap between the dams in which additional low cribwork was allowed to further diminish the available channel for vessels and fish. The low cribwork was installed in 1854.[1] The pressure and level of a larger supply quickly led to the embankment raising already noted, and to an 1855 widening of the aqueduct to about 75 feet; the Connecticut River Company later claimed 75-to-80-ton-capacity vessels could use the canal after this work. Originally, this structure was the narrowest and weakest point on the canal above the mill sites, creating difficulties in water delivery, and requiring several pier buttressing projects. The headgates were improved and later rebuilt c1856-64, with an added fourteenth gate, rack-and-pinion operators replacing the older wheels, and a gatehouse over the operators. In this same period, an undocumented "overfall" to control high water was installed in the towpath about 900 feet north of the uppermost lift lock. The overfall was replaced c1868 with a circular drain, enclosed by ashlar granite walls, which survives in modified form as "the Suckerhouse" immediately northeast of this lock (Connecticut River Company 1856-69; Baker and Tilden 1869; U.S. Circuit Court 1883; Raber 1989).

Low water summer flows soon proved a problem to the growing number of Windsor Locks canal industries, as discussed in section IV. Almost as soon as the low cribwork between the wing dams was in place, the Connecticut River Company began raising the cribs on its own volition, prompting protests from shad fisherman and some Longmeadow-Agawam area property owners which included an attempt to blow up the east dam in 1856 (cf. Kulik 1985). Although the canal commissioners ordered maintenance of the dams and channel cribwork at 1849 levels, the company began laying stone on the latter structures by 1859. Continuation of this practice through the Civil War effectively halted all boat passage, but as the shoaling below the rapids, discussed in section IV, was already probably severe the company apparently faced no serious protests. Additional water leases sold 1880-81 -- the first in about fifteen years -- contributed to the search for higher impoundment. Noting the lack of navigation above Hartford, the company successfully petitioned the Connecticut legislature in 1881 for a charter amendment allowing a permanent dam section joining the two wings. The entire dam was to have a higher level, and a central fishway which as built was about 40 feet wide and 14 inches below the crest elevation. A legal protest by the Holyoke Water Power Company in the federal circuit court prevented the dam, altered in 1882, from reaching its state-authorized height,[2] but the Connecticut River

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[1] The second wing dam may have been part of the design authorized in 1827 (cf. Anonymous 1827), and evidently required no further legislative approval; the company claimed more water was needed for boat passage in low water. Allowing the low cribwork between the wings probably reflects the very limited traffic on the river by 1849 for anything other than rafts.

[2] We have no information on the original dam height or pre-1849 canal water levels. The 1849 dam work was intended to yield a water level of 5.75 feet above the guardlock's miter sill, about 1.25 feet below the level authorized in 1881 and about .6 feet below the actual level achieved under court order

Company emerged with about another half foot of water to sell (Connecticut River Company 1856-69; U.S. Circuit Court 1882, 1884; Windsor Locks Deed Books 6: 301-4, 394-8, 407-9; 8: 362-6).

The 1884 settlement of the lawsuit basically precluded future raising of the crest elevation at any impoundment of the Enfield Rapids, and froze significant expansion of canal water supply. As with the 1849 dam work, the Connecticut River Company had to modify some engineering structures after the last dam enlargement. Sometime in the 1880s, the aqueduct was again widened, to about 102 feet on new downstream piers which replaced any towpath bridge, and the headgates were completely rebuilt as seven larger openings. Aside from 20th-century expansion and modernization of the Suckerhouse, and numerous repairs, these were the last significant modifications of the canal. The canal company planned to increase the average center depth from 6 to 7 feet in the 1880s by enlarging the canal, but instead opted simply to raise the water to within a few feet or less of the prism top (Porter 1885: 49). One maintenance consequence of raised water levels has been serious deterioration of unmortared rubble canal lining, fragments of which have eroded onto the prism slopes (Harte 1938; Lanati 1976; C E Maguire 1987; personal communication, 1988, John Robertson).

An effective freeze on new waterpower development capped the Connecticut River Company's income and its inclination to improve further its facilities. Even under the best of conditions, the canal retained many persistent delivery problems, including low seasonal flows, and winter ice at the headgates, in mill flumes or waterwheels, and at ice dams in the river which reduced effective head for mill operators (Porter 1885: 50-1). The canal company sold only three more new water power leases, all of them relatively small in size, between 1893 and 1911 (Windsor Locks Deed Books 8: 640-43; 9: 165-9; 16: 132-34). Significantly, the earliest of these was to the Windsor Locks Electric Light Company, a small local utility. By the end of the 20th century's first decade, the town's canal industries were turning to more steam- and electric-powered operations, and the Connecticut River Company itself sought to develop hydroelectric power as an additional, potentially major source of income. The company and other entrepreneurs became increasingly aware of the difference between the 20-35,000 hp potential of the Connecticut River at Enfield Rapids and the approximately 3500 hp actually developed along the canal (Connecticut Rivers, Harbors and Bridges Commission 1913: 32).

(Connecticut River Company 1856; U.S. Circuit Court 1884).

E. Corporate Changes, Declining Canal Use and Limited Maintenance, c1908-91

As discussed in section IV, the Connecticut River Company successfully opposed all proposed upriver navigational improvements after the Civil War, since the federal funds needed for new canals, locks, or dams could not be used to purchase the company's rights to divert river water. The rapid growth of electric utility interests early in the 20th century presented a new challenge which the company was less able to fend off: private construction of a higher dam at the foot of the rapids, for hydroelectric power generation. Two proposals for federal rights to develop the unused power at the rapids appeared in 1908 and 1909, one by the local Enfield Power Company and another by the Northern Connecticut Light and Power Company. The latter company, really held by the well-financed Northern Connecticut Securities Company, bought out both the Enfield and Windsor Locks power companies and became the Connecticut River Company's principal opponent for river water power rights. Initially, the hydroelectric proposals would have eliminated the navigational and water power values of the Windsor Locks Canal, with a high lock in a dam whose pool could drown the tailraces of the canal mills. The Connecticut River Company was now largely controlled by local industrial interests, principally the Coffin family who ran the C.H. Dexter & Sons paper plant. Reacting to these threats to its actual and potential uses of the river, the company in 1909 quickly arranged for a charter amendment allowing for power generation and sale, and presented its own proposal for a hydroelectric dam between the railroad bridge and the mills. This proposed dam lacked a lock, so as to continue the essential hindrance to navigation which the canal had become (Connecticut Rivers, Harbors and Bridges Commission 1913: 32).

The Connecticut River Company's proposal generated a complex series of maneuvers with Northern Connecticut Light and Power, executed among the older company's shareholders, the state legislature, the congress, and to some extent the public eye. The principal results, when some of the smoke cleared by 1914, were that:

> the Connecticut River Company surrendered its rights to collect tolls;
>
> all new dam proposals involved a navigation lock and a location above the Windsor Locks mills;
>
> Northern Connecticut Securities gained control of the Connecticut River Company by purchasing shares from Herbert R. Coffin's estate;
>
> all Enfield Rapids hydroelectric plans were halted when federal assistance to upriver navigation was tied to private payments to the government for any power rights developed (Connecticut Rivers, Harbors and Bridges Commission 1913: 33-7; Leuchtenburg 1953: 17-18; Connecticut River Company 1824-1933).

Northern Connecticut Light and Power now controlled the Connecticut River Company, and the two firms formally merged in 1926. A second round of planning for a new Enfield dam by Northern Connecticut c1928-31, was also dropped in the face of railroad opposition to navigation, failure to resolve the federal payments issue, and probably an insufficiently strong market for peak power to warrant the investment (Leuchtenburg 1953: 18-19). In 1936, the canal operations became the Windsor Locks Canal Company, a subsidiary of Connecticut Light and Power Company. By this time, canal waterpower income was probably declining in the face of

consolidation of metal processing industries and contraction of New England textile manufacture in effect by the 1920s. At the same time, recreational boat traffic through the canal was increasing somewhat in the absence of tolls, requiring maintenance of a non-remunerative navigational facility with a charter requirement for boat passage, while no efficient commercial use of hydroelectric power seemed possible in the canal. The company sold the old Windsor Locks Power Company station and its water priviledge to C.H. Dexter & Sons in 1942, and awaited an opportunity which never came to build a new Enfield dam (Connecticut Light and Power Company 1969).

A 1947-49 Army Corps of Engineers proposal to build a dam just below the railroad bridge, with a crest elevation about 6 feet higher than authorized in the 1880s, eventually gained Connecticut Light and Power support, with new peak power market projections, but foundered on opposition from Holyoke, railroad, and some Windsor Locks interests (Connecticut Light and Power 1969). Some local people feared the effects of a higher dam on the diminishing industrial base along the canal (Leuchtenburg 1953: 235-39). The power company was never able to secure all permits needed to proceed with this project, and by the 1970s faced continued maintenance costs and no water user tenants other than the Dexter Corporation, to which the Windsor Locks Canal Company was given in 1979. Dexter, using the water for industrial processing, has made some improvements needed to continue required flows and repair badly deteriorated features, and has considered developing a small, efficient hydroelectric project on the canal itself.

Canal modifications throughout this period involved only absolutely necessary maintenance or upgrading of antiquated operating equipment. Changes include motorization of the pulley on the Suckerhouse drain cover in 1936, the 1956-62 replacement of four of the six timber lift lock gates with steel, and recent
headgate operator modernization with either motorized rack-and-pinion operators or motorized steel rod gate lifts. The power company also conducted annual dredging of accumulated silt and sand, and masonry repointing or concrete reinforcement. Annual dredging was hand- and team-powered, using sledges and a 25-foot-long shovel. A chain attached to the shovel blade pulled the shovel along the canal bottom. These operations, most likely inherited directed from the Connecticut River Company, were directed at removing water-borne deposits while maintaining the canal lining intact. The Dexter Corporation has not continued dredging maintenance, but has repaired masonry and the aqueduct as necessary for minimal canal operation. Although modified by repairs, the Windsor Locks Canal retains much of its original form. Its spectacular setting and deceptive embankments -- which appear to be part of the land -- reflect a history of technical challenges and arduous construction (Connecticut Light and Power Company 1956, 1960, 1962; personal communications, Robert English, Edward Fairbanks, 1988).

VI. INDUSTRIAL WATER MANAGEMENT ON THE WINDSOR LOCKS CANAL

A. Water Rights

As shown in section V, the planners of the Windsor Locks Canal considered the potential for water power development along the man-made waterway. Board members located possible mill sites as early as 1825 (Erving 1925: 59). The fact that headgates and a 400' wing dam were built at the upstream entrance strongly suggests an intention to bring more water into the canal than was necessary for navigation purposes. The guardlock alone, with perhaps a short wing dam, would have been sufficient for the transportation canal that opened in 1829.

Using a transportation canal for waterpower was not unusual in the United States. In some cases, manufacturers took advantage of the water power potential at a particular lock, drawing water out of a canal above the lock and discharging it back into the canal below the lock. More often, the canal served as a raceway taking water from a river to a mill, which then returned it to the river. A canal that relied on locks to change levels might remain at an upper elevation while a nearby river dropped significantly through rapids or falls. If there were no topographical limitations, one could place a mill anywhere the difference in water level between the canal and the river was great enough to operate a water wheel. The mill would draw water from the man-made waterway, drop it through power-producing machinery such as a breast wheel, and return it to the river through a tailrace. Most canal historians, fascinated by the romance of canal boats and the mechanical ingenuity of locks, have ignored the value of transportation canals as sources of power for manufacturing.

The biggest problem for canals with dual functions was assuring that there was enough water to supply the demands of manufacturing operations. A lesser problem was excessive current created by supplying those demands (Malone 1983: 9; Connecticut Rivers, Harbors, and Bridges Commission 1913: 35). High currents hindered boat traffic, caused erosion, and could even be detrimental to waterpower generation. As long as mills on a canal did not demand too much water, the current in the canal would remain low enough for boat traffic. A well-designed canal with a cross sectional area of sufficient size could be both a feeder for water-powered mills and a man-made channel for transportation. The Windsor Locks Canal may have had serious limitations as a power canal, but in time it stimulated the establishment of many companies that depended on waterpower (see Table 1 and section V.C).

The Connecticut River Company, owner and operator of the canal, began leasing water rights in 1831, two years after the opening of transportation. Leases often included water lots along the east side of the canal, where tenants could erect their mills. Some leases also included building lots, on parcels owned by the company west of the canal, for worker housing or other facilities. Progress in luring industry was slow at first. As shown in section V, the company made very little money from water power until the late 1840s. Only six firms signed water leases before 1845. Power only became the principal source of income for the company after the railroad eliminated most of the need for river traffic.

The first lease of water power was by Jonathan Danforth. He got a water lot on the canal in 1831 for his casting and finishing shop (he made door butts) and the rights to draw water through a submerged opening, or "aperture," of 144 square inches. The aperture was to be made of cast iron in the shape of a square with 12 inch sides or a parallelogram of equivalent size (Windsor Deed Books 32: 277-9). Cast iron was considered a highly durable material which would not erode over time; the Connecticut River Company did not want an aperture to wear out and become larger than the lease allowed.

The many leases of water and water lots in Windsor Locks since 1831 followed a relatively standard pattern. Most, but not all, were for very long terms (999 years was common). Although some of the early leases restricted the number of hours in a day that a lessee could draw water, the Company had become more generous by 1838 (ibid 34:288-90, 35:278-9). Water twenty four hours a day, every day but Sunday, was the standard. The Company probably knew that most mills would not run all night, and it was apparently not planning for night storage in the pond above the dam. The rental fees varied; amounts ranged from $1 to $2.50 per square inch into the twentieth century (Windsor and Windsor Locks Deed Books; Shedd and Sarle 1911: 37), but one should add that water lots were often included in these leases.

The standard lease did not specify the exact head to be provided by the Connecticut River Company because it was subject to some fluctuation and because the available head increased in the distance between the northern and the southern water lots. This increase in head was because the Connecticut River continued to drop in elevation through Windsor Locks, while water in the canal stayed relatively level (there was some drop in the canal due to friction head losses). In other words, the drop or difference in elevation between the canal and a mill's tail race increased as you went further south (downstream). The Corps of Engineers estimated in 1905 that "the average yearly head at the mills at Windsor Locks" was about 26.7 feet and that there was a variation of one foot from the upper to the lower mill (U.S. Army 1905: 936).

The leases defined the cross sectional area of a durable aperture in the form of a parallelogram and set a maximum depth for that aperture. That depth in the normal lease was "no more than two and a half feet on an average below the true top water line of said canal, and in no part to be more than three feet below said water line (Windsor Locks Deed Books 9:165)." This limitation was meant to assure that the head pressure of water entering the various apertures was generally the same. Head pressure and the opening size would determine the flow rate, and thus the amount of water that could be used over a given period of time. With a standard depth establishing a relatively uniform head pressure, the Connecticut River Company could simply lease water by square inches. It was actually leasing flow rate, or volume per unit time; but this was theoretically proportional to the square inches of an aperture. In an age when measurement of flow rate was primitive at best, this was an understandable compromise.

In 1825 at Lowell, Massachusetts, a community which took hydraulic engineering and water power usage very seriously, the Proprietors of Locks and Canals began to lease water rights by units called mill powers, a system that was adopted by a number of large waterpower sites. These mill powers in Lowell were defined by specific flow rates (in cubic feet per second, or cfs) for each of the three drops (head measurements) on the Lowell canal system. However, until chief engineer James B. Francis developed precise and practical methods for measuring flow over weirs and in open canals in the 1840s and 1850s, there was little control over the water actually used by the manufacturing companies. Francis also experimented with turbine discharge rates at various heads and gate settings, so that the turbines themselves could be used as meters of water usage. In Lowell, aperture size was not a factor in water rights. Mills were allowed to have apertures, or maximum gate openings on a canal, of substantial size, but they were not supposed to take more water than an agreed amount. When there was sufficient water (in seasons of heavy rainfall) they could purchase "surplus power" beyond the "permanent mill powers" in their leases (Malone 1983: 6, 17; Francis 1855; Hunter 1979: 210-211, 229, 527).

Windsor Locks was not alone in its efforts to measure water usage by the cross sectional area of openings (submerged openings were apertures and surface openings were weirs). An important court case to settle conflicts over water rights in Pawtucket, Rhode Island (called the Sargent's Trench Case or Tyler et al. v. Wilkinson et al), in the early nineteenth century revolved around the size of the openings of flume gates and waterwheel gates. Many water power arrangements in the United States apportioned flow by reference to openings. A system of leasing water by square inches later became standard practice on the mining frontier of the American west. In California placer mining of the mid nineteenth century, the unit became known as the "miner's inch," and it traditionally referred to the flow through a one square inch opening under 6.5 inches of head (Young 1976: 122). This was less head pressure than allowed at Windsor Locks, and would therefore admit less volume of water per second through the same opening.

Professor David Greene, a consulting engineer for the Connecticut River Company in the early twentieth century, used a figure of .0644 cfs (authors' calculation from Greene's data) for the flow through each square inch of aperture opening at the standard depth of 2.5. feet (Shedd and Sarle 1911: 5-7, for examples) This assumption on his part simplified his determinations of power used by lessees, but it ignored variations that would effect flow rates. First, not all the openings were at the specified depth. Second, they did vary from the prescribed shapes. Third, there would be some scale effects depending on the size of apertures.

As late as 1969, a Northeast Utilities engineer's tabulation of existing water leases computes cfs "using constant head called for in lease." However, the accepted figure for flow rate in 1969 is only .0546 cfs. per square inch of aperture, a lower rating than Greene's. The .0546 figure is very close to the one used by Dwight Porter in 1885 (Porter 1885: 49), which was based on Trautwine's measure of flow through a one inch aperture under 30 inches of head. Greene may have used a larger figure because much of the cross sectional area of any aperture on the system was going to be under more head than 30 inches. The engineer in 1969 ignored his own evidence (dimensioned drawings done in 1964) that the apertures actually had varying heads. For

instance, the top of the aperture at the Clark Building (then owned by Dexter) is shown at 58.5 inches below the normal water surface. In his letter to the Corps of Engineers, he says:

> For your information, our contract negotiations with the Lessees are on a square inch of opening basis and not on water quantity. We are including certain information that will allow you to obtain water usage rates, if you so desire." (Bisio 1969)

Even if the flow rate had been the same per square inch for all the apertures on the canal, the Connecticut River Company would still have had to enforce the limitations on the depth and the size of the apertures in each lease. Yet evidence suggests that companies did not stick to the legal limits for their apertures. In 1857 the board of the Connecticut River Company reported that manufacturers were"in many cases" drawing "more water than is permitted by the leases." The board had collected money for some of this excess in the last six months, but it recommended that "some authoritative course be adopted, by which the amount of water drawn at each mill may be accurately measured, and rent collected for all excess of water used, at the rate of two dollars an inch, or the Lessees confined to their leases (Connecticut River Company 1857: 4)

The only drawings of actual apertures that have surfaced (no pun intended) are the ones Bisio used in 1964 and several done for the Dexter Corporation (C.H. Dexter Division 1977, 1979). Combined with the tabulations of 1969, they show considerable increases over the cross sectional areas specified in leases. They also show that firms went to circular apertures (by hydraulic theory, the most efficient shape) or geometric shapes that combined straight lines and circular segments. None of the apertures is a parallelogram, as demanded in the standard lease language. One table compares the "entitled" square inches with the actual dimensions of flume openings. The Montgomery Company, which by 1969 was using only a small amount of water, had leases amounting to 800 square inches; but the actual area of the company's three flume openings was 15,793 square inches, an excess of 14,983 square inches over the entitled area. C. H. Dexter & Sons, which had acquired entitlement to 5024.5 extra square inches in addition to its original leases, still had an excess of over 10,000 square inches in its various flume openings (Bisio 1969).

It should not have been too difficult to check on the size of apertures at each water privilege in Windsor Locks, but the Connecticut River Company seems to have done little to enforce compliance with aperture limitations. The company officials may have been too embarrassed by the inadequacies of their canal to put heavy pressure on their lessees. The Company had problems living up to its side of the lease agreements; it did not always deliver the promised water at the proper elevation. And lessees sometimes could not make effective use of the water that was delivered.

Three troublesome characteristics of the river had a lot to do with the company's problems. One was the river's high flow rate in wet seasons. Another was its low flow rate in dry seasons. The third was the river's tendency to produce ice in cold seasons. All of these reduced the power that was available at mill privileges on the canal. We could also add to the list of power reducers the pickerel weed that thrived in the canal and the sediments that freqently built up in it. The canal company used a dredge for sediment removal and a mowing machine to deal with the obstructing pickerel grass, "a growing evil

in all Canals of less depth than seven feet, or where the navigation is moderate" (Connecticut River Company 1861: 5).

The Connecticut River was naturally subject to wide fluctuations in flow rate. Seasonal rainfall patterns were largely responsible, but man-made alterations to the drainage basin also had an effect. Filling of marshes that once stored and slowly released water contributed to rapid runoff in the spring and reduction of flow in the summer. Deforestation produced similar results, a point noted by the Company: "There is another effect incident to the clearings of forests at the head-waters of the Connecticut, viz., extreme low water in the summer " Droughts sometimes made it very difficult to supply the needs of lessees, forcing the company to such extreme measures as temporarily putting obstructions in the channel at the dam (ibid.: 4).

High water was as bad as low water. Floods not only did heavy damage to the canal and dam on many occasions but also prevented full use of water for power generation. When the river was high, water backed up into the tailraces of mills. This "backwater" could impede the rotation of water wheels, sharply reducing their efficiency (ibid. 1858: 4-5). Even with turbines which were designed to run submerged, the rising water in the tailrace reduced the head available for power generation (roughly equal to the difference in elevation between the water supply in the canal and the tail race water). The company was not legally responsible for backwater caused by freshets or floods. It had simply agreed to deliver water to the lessees. Although it could not charge them for water that was not delivered because water control structures or canal walls failed to resist the assault of a flood, it could charge them for the water it made available during backwater conditions. The water might not have much, if any, value for power generation in those conditions, but it was available in the canal as required by the lease.

Water was high for much of the year in 1857, and backwater became a very serious problem. The Connecticut River Company had planned to do "accurate admeasurements of the water drawn from the Canal at each Mill," but the river was too high to do the measurements. In the last six months of the year "there was such a financial backwater as to submerge most of the Wheels." The board decided to put off any effort to measure water use and to charge for the excess, "considering themselves fortunate in being able to collect even the amount specified in the Leases" (ibid.: 4-5).

When backwater conditions diminished the amount of power generated per cfs of water at a mill privilege (because of resulting reductions in efficiency, net head, or both), one response was to use more cfs (more flow) to get more power. This option was, of course, subject to the limitations of gates, flumes, and wheels. If the canal was in good order, backwater could, however, aid a mill owner since there was a lot of water available during the freshets that produced this condition: one had a greater than normal water supply if one could use it.

Owners of canal systems usually went along with this use of excess water, realizing that they had water going to waste and mill owners who were temporarily suffering from inadequate waterpower. The 1834 lease agreement between the Connecticut River Company and the owners of the Williams and Hollister paper mill called for a 300-square-inch aperture, but also allowed an additional 50 square inch aperture for use during those times when the Connecticut River flooded their wheels (Windsor Deed Books 33: 274-6). This formal arrangement was unusual; in most cases it seems that the Connecticut River Company simply overlooked or unofficially approved larger apertures for use during backwater conditions.

Because of the persistent problems with backwater, one can understand the reluctance of a mill owner to limit himself to an aperture matching his water lease. He could still limit himself to the leased aperture with a larger opening partially blocked by a headgate. When backwater reduced his power, he could open the gate further and draw the excess water he needed to maintain his normal power level. He might reason that what he deserved for his lease payments was a reliable level of power, and that he was only taking more water than normal when backwater forced him to do so. The Connecticut River Company probably turned a blind eye to this practice, in the interests of satisfying the legitimate complaints of their lessees. In 1864, the board reported that "An additional Water Wheel with shafting and pulleys, has been put into the Cotton Mill, to give the required power through freshets (Connecticut River Company 1865: 4." An additional wheel would not have been any use in freshets without a way of admitting extra water. This mill was owned at the time by the Connecticut River Company, so they understood the problem - and the solution.

Ice could also hinder the operation of water-powered industry. Although the leases specified that "obstructions from ice" were not grounds for refusing to pay water rents (Windsor Locks Deed Books 9: 165), the Connecticut River Company met some resistance from lessees whose water supply was diminished by ice problems. Ice flows in the river did serious damage to the dam on several occasions. Anchor ice, small particles that form in moving streams, could build up on gates and at the trash catching racks at the entrances to mill flumes. This ice build-up could restrict or even stop flow into mills. The Seymour Paper Company in the 1880s sometimes had to "keep a man at work all night raking anchor-ice from its rack, and has also to introduce a jet of steam into the flume to disperse it there and keep it from the wheels" (Porter 1885: 50-51). Ice jams at the entrance to the canal could limit the flow of water; then the level in the canal would drop as mills drew water during the workday. Near the lower end of the canal, where current was minimal (because much of the flow had already been taken by upstream privileges), the surface tended to freeze over in severe cold. If the canal dropped in level during the day, the ice also dropped. Then additional water flowed in at night (when most mills were shut down), rising over the partially sunken ice and soon adding another frozen layer to it. This "...rapidly increased its thickness, until in some places it measured 48 inches of solid ice. With such an obstruction, it was impossible to supply fully the Mills at the lower end of the Canal" (Connecticut River Company 1869: 3-4; 1857: 4; Porter 1885: 51).

That lessees were willing to put up with ice problems may have made the board more tolerant of their aperture excesses. Not all the lessees accepted the ice excuse, however:

> Most of the Lessees appreciated the cause of the trouble, and made no needless complaint. But at one of the Mills, the Lessees were refractory, and did violence to the Company's works. This resulted in a lawsuit, which terminated in their withdrawing the case, and signed obligations by the conditions of their lease (Connecticut River Company 1857: 3).

Ice could also cause backwater problems for mills. When ice jams held up the flow of the main river below Windsor Locks, water would rise behind the jam and create flood conditions for mills in the city. The government pier that jutted into the river 5 or 6 miles south of Windsor Locks in the 1880s was for some years a source of terrible ice jams. It caused backwater and thick ice formation as far upstream as Enfield Falls (Porter 1885: 50).

An undated staff report by the Montgomery Company has a revealing section on "Perversity of water power" at Windsor Locks:

> In the late summer he [J. R. Montgomery] was often troubled with insufficient water to drive his spindles. In the winter his penstock might freeze or his intake racks sometimes clogged with ice. At other times, trash would also block the intake, stopping the flow of water. Several times the plant was inundated as the result of high water (Anonymous c1971).

The leases provided a mechanism for lessees to deduct from their fees all rent for days in which the Connecticut River Company failed to deliver the quantity of water leased. When the dam was being repaired (after damage by "...a heavy body of ice..." in the river) in 1868, the board reported that "...there was during a portion of a few days, some low water in the canal, which the refractory Lessees made the occasion of refusing to pay their last six month's water rent" (Connecticut River Company 1869: 4).

Every lessee had to have a "good and substantial gate or gates" that could shut off all water through an aperture into a flume. If water was being wasted "for want of proper repairs" or "if more water be used than is hereby leased," the lease allowed the Canal Company to close the company's gate or block the aperture in some way. It could then sue for damages (Windsor Locks Deed Books 9:165).

The water leases were also a way to restrict the type of industry that could be located on the canal. A company could not lease a water privilege for one purpose and switch to some unacceptable operation at a later date. The following type of restrictions appear in leases:

> The second party and their assigns, shall not use any of the water hereby leased and demised, for a distillery, laboratory, or other offensive chemical works; for making varnish, vitriol, spirits of turpentine, nor gun powder, nor in a pottery, nor in any other works which may be so noxious from fire or otherwise, as to impair, injure, or endanger the life, safety, or reasonable comfort of any person...on the premises of the first party (ibid.).

When a company failed or sold out to a new firm (a frequent occurence, as one can see by scanning Table 1), the Connecticut River Company

would either find a new tenant/lessee or make some arrangement with the succeeding firm for continuation of water power leasing. C. H. Dexter & Sons, for instance, took over the buildings and water rights of several other firms. If sufficient water was available, a new enterprise could purchase more water than the previous lessee was using and install an additional or bigger aperture. Also, long term users of water power, like the Eli Horton Company, could acquire an additional lease or buy entitled excess water (Windsor Locks Deed Book 16: 132-13; Bisio 1969; Shedd and Sarle 1911). However, there was not much additional water available after a court decision prohibited further raising of the dam in the mid 1880s (U.S. Circuit Court 1882, 1884). Leases became primarily a way of re-apportioning the existing supply of water.

The founders of the Connecticut River Company may have thought about waterpower and industrial development when they planned their canal, but they were primarily concerned with the potential for profit from navigation. They never expected to depend on industrial lessees for the vast majority of their company's income. Times changed, and canal navigation soon lost its luster. However, the demand for waterpower, particularly waterpower on a large scale, increased throughout the 19th century. The potential for waterpower at Windsor Locks was very impressive, but the canal, unfortunately, was not. That the canal was better suited for navigation than power production was the result of poor planning by its founders, or to be more generous, failure to read the future.

B. Waterpower

The Corps of Engineers estimated that the total power generated at Windsor Locks in 1905 was 3100 net horsepower (using an average efficiency rating of 75% for the turbines). They accepted the figure of 1420 cubic feet per second from David Greene of the Connecticut River Company while differing with him somewhat on head measurements. When Dwight Porter had studied the Connecticut River for the U. S. Census a quarter of a century before, he found only between 1800 and 1900 net horsepower utilized. The gain in power by 1905 was substantial in terms of percentage, but it was still far short of what could have been developed.

In his 1885 report, Porter recognized that the river had the potential to provide much more power at Windsor Locks. He also saw that the potential would never be realized with the existing canal:

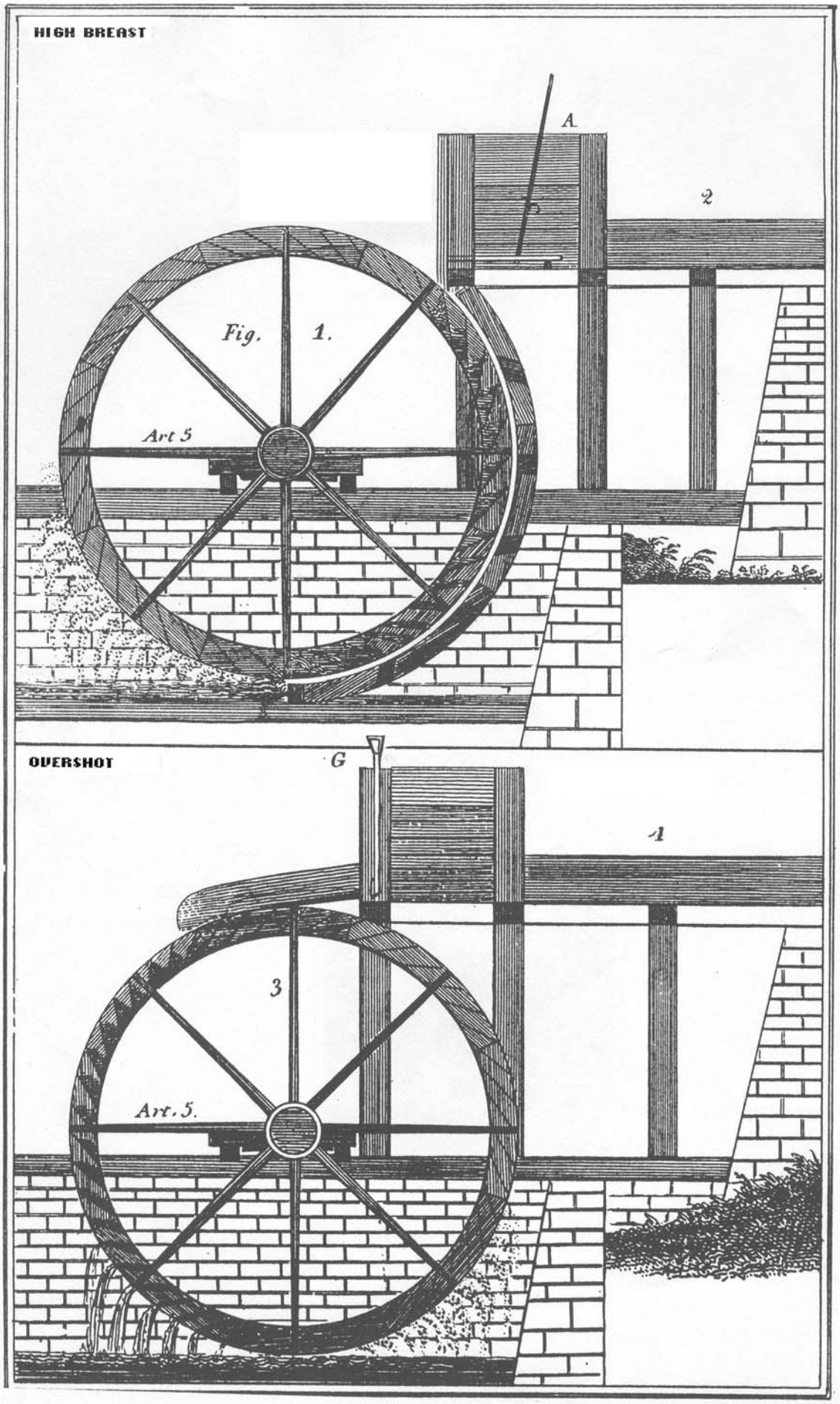
> With the fall at command at Windsor Locks the amount of power to be obtained from the Connecticut River is theoretically very great, though for realizing it most thoroughly, the present improvements are not the best suited. A canal of so great length as there employed has evident objections aside from the original cost, and by the location of the dam so far up stream a considerable amount of available storage room is lost. It is to be remembered, however, that the hydraulic works were designed mainly for the assistance of navigation, and they are therefore not to be judged wholly as waterpower improvements (Porter 1885: 50).

Porter was a practical engineer. When he looked at the flow in the Connecticut River, he wanted to know how much power the river could provide during low water periods in an average year, as well as what was available ten months out of an average year. Later studies would suggest that the river could provide as much as 35,000 gross horsepower at Enfield Falls, but they did not consider the reality of rapid runoff in spring floods, the annual dry spells, or the legal resistance to a new dam. Average annual flow in a large New England river is usually considerably higher than the power that is available for 10 months in a year (for the Merrimack River in Lowell it is about twice as high) and is always far above the low flow rates for July and August. Porter's estimates of the flow available for 10 months was 6,200 cfs, which he compared with a figure of 4,900 cfs for low water. One would get far more than 6200 cfs much of the time, but could count on at least this amount in all but the driest periods. For a head of 28 feet, he calculated the average gross horsepower from 6200 cfs as 19,700 (equal to about 15,000 net horsepower). This stands in sharp contrast to the 2500 gross horsepower (about 1900 net) that was then being utilized on approximately the same 28 foot drop in Windsor Locks. Using a head of 33 feet, which was possible with a new dam, he calculated 23,240 gross horsepower (about 17,500 net) for the same ten months (ibid.). Even with the increase to 3100 net horsepower by 1905, the Connecticut River Company was using only about a fifth of the readily available power (15,000 net horsepower as a very conservative estimate).

The efficiency rating of 75% used to calculate net power from the gross figures given above is a reasonable estimate for good reaction turbines of the late nineteenth century. They could harness, or make available for manufacturing, about 75% of the potential water power delivered to them. This is an average figure, however, and an estimate based on the performance of many turbines running at full gate settings. It would be too high for the average efficiency of turbines at less than full gate, and for the breast wheels that turbines replaced in most New England mills.

Because of problems due to backwater, it is likely that the first wheels in Windsor Locks were high breast wheels. These were a type of wheel which combined adequate efficiency (in the range of 60-70%) with relatively good performance in moderate levels of backwater. They, like overshot water wheels, used the weight of water in their buckets to develop power. In both the high breast and overshot types, water entered buckets near the top of the wheels. However, breast wheels rotated in a direction opposite to that of the overshot wheels; they turned towards the flow of water into the buckets, instead of away from it. This rotational direction gave them an advantage in backwater conditions, because water left the buckets at the bottom with a push out of the wheel pit. When turning through backwater, a breast wheel was creating currents away from the wheel and in the direction of the tail race; an overshot wheel was merely wallowing in the backwater and losing a great deal of efficiency as it turned against it (Figure 3).

Figure 3. WATERWHEEL TYPES
source: Evans 1850 Plate. XV.



This relative advantage of the breast wheel over the overshot wheel should not, however, be interpreted as a solution to the problem of backwater. Breast wheels did suffer loss of efficiency in any backwater and could be slowed to a crawl if they had to turn through more than four or five feet of water in their wheel pits. The backwater mentioned in the 1858 report from Windsor Locks was sufficient "to submerge most of the wheels (Connecticut River Company 1858: 5)." As mentioned above, the cotton mill had to put in an additional water wheel in 1864 to help the mill run during the freshets that created backwater (ibid 1865: 4).

Only the most progressive manufacturers switched from water wheels to reaction turbines in the 1840s, when the Franklin Institute in Philadelphia began to publicize the capabilities of these prime movers and James B. Francis was proving their effectiveness in a series of tests at Lowell. A reaction turbines was a highly-efficient water motor which used the pressure of water passing through the buckets of a runner to generate power. Despite the clear superiority of turbines (especially in backwater), many mills continued to install breast wheels into the 1860s, as the cotton mill in Windsor Locks may have done in 1864. There should have been no doubt about the need to replace breast wheels after the 1855 publication of Francis' Lowell Hydraulic Experiments, but technology does not change as rapidly as we often assume (Francis 1855; Malone 1983: 15-17; Malone et al 1989; 13; Hunter 1979: 292-342; Reynolds 1983: 338-349).

Turbines were superior to breast wheels in many ways. All the various types of turbines shared one characteristic: they ran at very high speeds. French engineers, who deserve most of the credit for the early development of reaction turbines, called them the wheels of "grande vitesse," or high speed. It sometimes took a great deal of gearing and pulleys to convert the slow rotational speed of a breast wheel (5-7 r.p.m.) to the high shaft speeds needed for most manufacturing operations.

Turbines were much smaller than breast wheels and usually easier to install. Breast wheels had to be laboriously assembled in a large wheel pit, by skilled craftsmen. A turbine could be ordered from a manufacturer and shipped either intact or as a few basic subassemblies that were easy to put together. They took up much less space in the basement of a factory and could be put in the existing water wheel pits of operating mills.

Breast wheels, particularly the composite wood and iron forms that were most common in the mid-nineteenth century, wore out quickly, often requiring expensive repairs in only a few years. By 1863, the water wheel at the cotton mill in Windsor Locks was apparently beyond repair:

> The Water Wheel at the Cotton Mill, fails to give the required power, in consequence of its worn and somewhat broken condition. A new wheel and flume must be put in the coming season (Connecticut River Company 1864: 6).

Manufacturers of turbines almost always made them of iron (and later of steel). This tough metal was extremely durable, giving turbines a good reputation for longevity. Large numbers of nineteenth century turbines survived into the mid twentieth century, many of them performing well after more than half a century. With occasional replacement of key parts such as runners, turbines could be expected to last for many decades. The first Francis turbine, installed in Lowell in 1847, was run (without any known repairs) until 1923. It is still in good shape today, demonstrating its corrosion resistance in a flooded wheel pit (Malone and Weibel 1985; Malone 1986: 16).

Efficiencies of reaction turbines were above those of breast wheels. Seventy five per cent efficiency was common and some nineteenth-century turbines would regularly provide efficiencies as high as 85 per cent under good conditions. This meant more power for the same flow of water with the same head. A turbine could pay for itself in just a few years by providing more power than a breast wheel could at the same site. If the site was prone to backwater, as the water lots at Windsor Locks were, the turbine would be an even better investment.

Reaction turbines ran submerged, and their efficiency of power generation was not effected by moderate backwater. Unlike breast wheels, water in a wheel pit did not impede their rotation. If water rose in the pit because of backwater, it would reduce the net head available for power generation (and thus reduce available power) but would have little effect on the efficiency of the turbine itself. Although there might also be some loss of efficiency if the net head dropped below the design range of the turbine, this type of water motor was able to function in most high water conditions.

Turbines could even take advantage of increases in head because of the raising of dams or improvements to canal systems. One would need to install a bigger breast or overshot wheel to make use of the greater head in such a case. Where water levels fluctuated during the day or by season, the turbine was best equipped to deal with the changing head. More head just meant more pressure against the buckets of a turbine runner and therefore more power.

Once a wide range of turbine forms and sizes were developed in the period after the Civil War, these prime movers were often reasonably priced. It took relatively little engineering skill to select a turbine using authoritative tables of performance characteristics produced by independent testing facilities. To make an informed decision one needed to know power demands and the available flow and head at a site. Then one could compare relative efficiencies of types made by various turbine manufacturers, assess reputations for reliability and durability, and decide what one wanted to pay. It was more difficult to judge performance based on the various gate settings one might use, but this data was available.

The conversion to turbines in Windsor Locks probably occurred in the 1850s and 1860s, and was complete among waterpowered firms on the canal by 1880 (U.S. Census Bureau 1880). There is limited information available on 19th-century turbines in Windsor Locks, but we have excellent information about the turbines that were in place in the twentieth century, and those that are still running today. The "Estimates in Reference to Use of Water at Windsor Locks" prepared by consulting engineers in 1911 (Shedd and Sarle 1911) is a detailed listing of all turbines, estimated discharge rates, and lease/usage data. In addition, the Dexter Nonwoven Division has provided specification sheets (Dexter Nonwovens Division, #3-5 waterwheels) on the three turbine units that they operate today, only one of which is run most of the time: a 38-inch vertical Francis-type mixed flow built by the Rodney Hunt Company and installed at an unknown date. The older operable turbines at Dexter are a 1906 Holyoke 33-inch horizontal double runner unit, built in about 1906 (listed in Shedd and Sarle 1911: 19 as one of the great Hercules designs by John B. McCormick of Holyoke), and a c1920 S. Morgan Smith 27-inchunit, also with a horizontal double runner.

The turbines in the 1911 study include examples of most of the best-known nineteenth-century patent wheel types (McCormick, Jolly, Risdon, Hercules, Leffel, Risdon, Hunt). Catalogs for almost all of these types, and for the S. Morgan Smith turbine, are available in the extensive Kinne Collection of turbine materials at the Old Sturbridge Village Research Library (Kinne Collection Checklist 1977). There are also independent test reports produced by the Holyoke Testing Flume and by such quirky "authorities" as James Emerson (Emerson 1892).

In addition to mixed flow vertical and horizontal turbines, there were four large Boyden turbines in place in 1911, all at the Windsor Paper Company Division of the American Writing Paper Company and installed between 1883 and 1904. Boyden turbines were outward flow types originally developed by Uriah Boyden in Lowell in the 1840s from the French Fourneyron design. They required large, usually circular, wheel pits because water discharged in a circumferential pattern from these vertical units. Francis did his first series of turbine tests on Boyden's wheels in Lowell's Appleton Mill in 1846. The Shedd and Sarle report used Francis' tables to calculate Boyden wheel discharge. The largest at Windsor Locks had a runner 84' in diameter (Shedd and Sarle 1911: 2-3, 19; Francis 1855: 1-54)

There were also some less common turbines on the canal in 1911, including a 42" Blake and a 36" Chase, the latter made in Windsor Locks and used at the lower cotton mill of the J. R. Montgomery Company. Most Chase turbines were made in Orange, MA. This one was used 13 hours a day with a generator to run electric lights in the mill (Shedd and Sarle 1911: 15, 19-20).

Hydroelectric generation was a natural evolution for water power. Water power competed with steam power for most of the nineteenth-century, leading easily in popularity through the 1850s, then falling behind in terms of total installed power by 1870 (Hunter 1979: 481-536).[1] Although the growth of steam power continued to outpace that of water power, widespread use of electric power for lighting and motive power in the late nineteenth and early twentieth centuries created greater demands for both steam and water power. Because electrical power could be transmitted over considerable distances with relatively little energy loss, many potential hydro sites which had been uneconomical to develop in the age of mechanical power transmission were suddenly valuable locations for electrical generation. Sites like Windsor Locks which had existing waterpower systems but did not make full use of their waterpower potential became likely candidates for major hydroelectric redevelopment plans (See Chapter V). A mill no longer needed to be at, or even near the fall that supplied its energy. Also a large cluster of mills could be powered from one or more central stations, eliminating the need for separate turbine/generator installations in each mill or mill complex, and for delivery of water to all the manufacturing sites (Malone 1978: 34-35). WE WILL USE SOME ADDITIONAL DATA ON WINDSOR LOCKS MILLS STEAMPOWER IN THE FINAL REPORT.

Although Edison's light bulb won much quicker acceptance than did electric motors in textile mills, the age of electricity had a significant impact on the factory system by the beginning of the twentieth century (Bonham 1973: 283-378). From 1890 to 1930 almost all of the major water powered mills in New England began to either generate their own electricity for manufacturing or to purchase it from power companies. In 1893 the Connecticut River Company leased waterpower to the Windsor Locks Electric Light Company; we are unclear as to whether this firm provided power to canal-side industries (Windsor Locks Deed Books 9: 165-169). The J. R. Montgomery Company followed the normal pattern in textile mills, using electricity first for lighting and later for motor drive systems. Later Montgomery actually manufactured components used in electrical equipment.

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[1] In Windsor Locks, as in most industrial communities with substantial waterpower, steam was primarily a supplement for waterpower. It allowed for industrial expansion after the limits of a waterpower system had been reached, and it was a reliable back-up when that system was not performing well because of floods, droughts, ice, breaks in the canal, etc. In addition, there were often economic advantages to steam power in particular manufacturing operations where steam heat for processing was necessary anyway (bleaching, dyeing, wool scouring, etc.), or where there was a great deal of scrap wood that could be used as free fuel (sawmills, woodworking shops, etc.). Windsor Locks mills were well located for steampower because, after 1844, they abutted a major rail line as well as the canal, both of which could deliver coal. With the dramatic improvements in steam engine efficiency as a result of work by James Corliss and others by the 1860s, steam became much more competitive (Hunter 1985; Malone 1983: 20-22).

A combination of the Great Depression, the decline of the New England textile Industry, and the widespread availability of cheap fuel oil made water power developments much less valuable in the 1930s. Most water-powered mills by then had some kind of electrical generation on site, but they were reluctant to put more money into repair or replacement of their hydroelectric plants. When something went wrong with installed equipment or with the engineering features necessary to deliver water to a wheel pit, executives often decided to purchase electricity from a power company. In most cases they were already customers of the power company, using their own capacity for only part of their needs.

The Dexter Nonwoven Division is the last user of waterpower in Windsor Locks. Dexter actually uses very little water for power today, as noted above. The main reason for Dexter's takeover of the canal was to assure a supply of process water for its industrial operations. There have been a number of leases of water by the Connecticut River Company for process needs, and devices like the Barber Suctions at C. H. Dexter and Sons (Shedd and Sarle 1911: 10-11) to draw such water into the mills. Since Dexter maintains an expensive canal system to deliver process water to its mills, it uses its three remaining, operable turbines/generators to generate some of its electric power (personal communications, Peter Barley).

VII. HISTORIC INDUSTRIES

A. Summary

Historic industrial development in or near the proposed Heritage Park area falls broadly into three classes:

enterprises pre-dating the Enfield Canal, most of which developed on Connecticut River tributaries to serve local agrarian economies;

firms using land or water controlled by the Connecticut River Company, emerging along the east side of the canal in Windsor Locks c1831-1946;

a small number of firms which developed away from the canal in Windsor Locks' growing industrial center, c1860-1900.

1. Pre-Canal Industries

Prior to Enfield Canal construction, Suffield, Enfield, Windsor, and East Windsor were predominantly agricultural towns. Grist, saw, and fulling mills appeared on local streams to process household grain, lumber, and woolen or flax cloth goods. Flax also supplied linseed processed at local oil mills, and cider mills flourished as well. Stony Brook in Suffield, although an irregular water power source, ran the earliest and most numerous mills in that town, beginning with John Pynchon's 1672 saw and grist mills, and including an 18th-century fulling mill (Sheldon 1879: 8; Alcorn 1970: 8-13, 44). In the Pine Meadow section of Windsor, Kettle Brook ran a Denslow family sawmill by 1742, just west of the later canal. The Haskell and Dexter families bought this site in 1767, as well as a second dam site upstream at which Seth Dexter [II] (1743- 1797) began a fulling mill in 1770. A gristmill was added to the sawmill site in 1784. The fulling mill was sold in 1817, but the grist and saw mills -- run by Dexter family interests after 1817 -- became the base for an extensive specialty paper mill on the canal, discussed below, and operated into the 20th century. Alexander Allen and Eliakim Gaylord began a second Pine Meadow grist mill in 1781, on Pine Meadow Brook (Waterworks Brook) at the south end of present Windsor Locks. The Pine Meadow and upper Kettle Brook mill sites remained useful water privileges late into the 19th century (Stiles 1892, I: 500-509).

The widespread colonial saw, grist, or fulling mills arose almost anywhere that skill, money, and adequate waterpower were available. Less common industries, more dependent on natural resources or regional location, also emerged in the Enfield Rapids vicinity. Suffield's shallow wetlands included bog ore from which three local water-powered bloomeries made wrought iron tools for predominantly local needs, from the early 18th century into the early canal era.[1] At one of these operations, Luther Loomis and Eleb Foxon are reported to have made shovels for sale to Enfield Canal contractors (Sheldon 1886; Clark 1969; Alcorn 1970: 27, 41). An ironworks in Enfield, established on the Scantic River in 1802, made agricultural implements until c1860 (Winch 1886: 156).

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[1] Bog ore, a renewable resources, forms as iron in ground water meets oxygen sources. Layers of ore gradually consolidate on wetland bottoms. Small bloomery forges could convert the ore directly to wrought iron with water-powered ore crushers, hammers, and hearths.

Located near the foot of Enfield Rapids, the Pine Meadow and Warehouse Point villages were well-placed to manufacture and ship commodities for the coastal and West Indies trades. By the early 19th century, gin distillers operated on both sides of the river, part of a large Hartford county trade which capitalized on the river route and the lowland climate conducive to rye culture. East Windsor had six distilleries by 1819, the largest of which were at Warehouse Point. In Pine Meadow, the Haskell family began a water-powered gin distillery in 1811 on Adds Brook, just south of Kettle Brook and east of the later canal, which became the first site to draw water power from the canal prior to the mill's closing during a temperance movement in 1833. Local distillers made use of river ice, and are said to have built the earliest underground ice houses in New England after a c1811 flood piled up small mountains of ice along Pine Meadow Brook which lasted until the summer under the stream banks. Local distilling lasted into the early canal era, but was damaged by the 1810 Hartford bridge, along with some other local trades such as ship-building which depended on river transportation (Pease and Niles 1819:65-6; Stiles 1892, I:5-4-5; Hayden 1900:27,74; Allis 1939:111-12; McClure 1949:13; Anonymous 1954:13-15).

Cereal crop distilling was one of several Federal Period strategies practiced by local landowner-merchants searching for new investments in the face of depleted natural resources, trade fluctuations, or fortuitous opportunities. In Suffield and East Windsor, small-scale manufacture of cigars from local leaf flourished for several decades, c1810-30, after the adoption by Samuel Viets of methods imparted by an unnamed itinerant Cuban cigar maker. Specialized production of Connecticut Valley cigar wrapper after 1830, for final cigar assembly elsewhere, ended the growth of local cigar plants (Sheldon 1886; Ramsey 1930: 126-30; Alcorn 1970: 117). The most durable of the pre-canal industries was paper manufacture, begun locally near the mouth of Stony Brook in 1801 by Harvey Bissel and Henry Pease. Located at the 17th-century Pynchon mill site, this mill at various times made writing, cartridge, and tobacco shipping paper under various owners, and after burning three times was finally closed in 1914. C.H. Dexter & Sons leased the site, long known as the Franklin Mill, in the 1870s and purchased it in 1901. About 1.5 miles upstream, the Eagle Mill begun by Simeon and Asa Butler in 1816 operated until it burned in 1877, and was known as the first mill to supply paper to the federal government (Anonymous n.d, 1929, 1988: 57; Alcorn 1970: 113, 119). Papermaking became a canal-era industrial focus in Windsor Locks, along with some textile manufacture. Early ventures in this latter branch of industry included a reported 1795 cotton mill on Stony Brook (possibly a fulling mill operation); Suffield had four reported cotton mills by 1819 (Pease and Niles 1819: 87). Other significant pre-canal textile operations began in Thompsonville in 1828, with the earliest local carpet mills (Winch 1886: 156-7).

Inhibited by limited power sources and regional transportation, and without benefit of the mechanized equipment and machine tool availability which flourished after c1840, the pre-canal local industries were generally short-lived. Few of them survive in any recognizable physical form, aside from fragmentary Franklin mill dam remains on Stony Brook. Two Suffield men, Peter Olcott and John Ely, made the first attempt to tap the larger but less manageable power of the Connecticut River in 1787, building a dam in the river channel west of Kings Island (which they then owned) for a projected, unidentified mill site. No mill was ever built, and the dam washed out in 1810 (Pease 796; Ball 1944: 14-15; see Barnard 1827). Local industry did not flourish until the combination of relatively reliable river water power and freight transportation, which only coalesced at Windsor Locks after 1844.

2. Industries On the Windsor Locks Canal

When completed in 1829, the canal was no more than about 100 feet from the riverbank through the village of Pine Meadow. The industrial core of Windsor Locks grew along some 4500 feet of this narrow strip, beginning about 700 feet north of the lift locks. This was the only area in which waterpower from the canal could be developed near early road and ferry facilities. Beginning in 1831, over forty companies operated mills or factories here, at sixteen different locations (Table 1, Figure 3). Despite the waterpower limitations discussed in section VI, the canal provided one of the largest industrial power sources in southern New England available before c1845, and attracted three principal types of firms:

paper companies, usually drawn here by the availability of wood pulp from upriver sources (about 25% of the Windsor Locks firms);

textile companies, emerging from New England's earliest factory mode of industrial production (25-30% of Windsor Locks firms);

metal-forming and machine tool operations, frequently started here in response to equipment and machinist requirements of the paper and textile firms (about 15% of Windsor Locks firms).

Table 1 summarizes the histories of most documented firms, important examples of which are reviewed in more detail below. The chronologies of site development suggest that locations near the ferry to Warehouse Point were initially the most desirable, perhaps to combine the best transportation point with the advantage of a slightly greater fall of water available at more northerly points on the canal. The exceptions to this pattern are the Dexter and Haskell-Hayden mills, built on land already owned by these families, and the sawmill at the uppermost site, where a basin created by canal construction over a small drainage allowed for storage of log rafts (Windsor Deed Books 34: 288-90).

Figure 4. INDUSTRIAL SITES ON LANDS OF THE CONNECTICUT RIVER COMPANY (see Table 1)

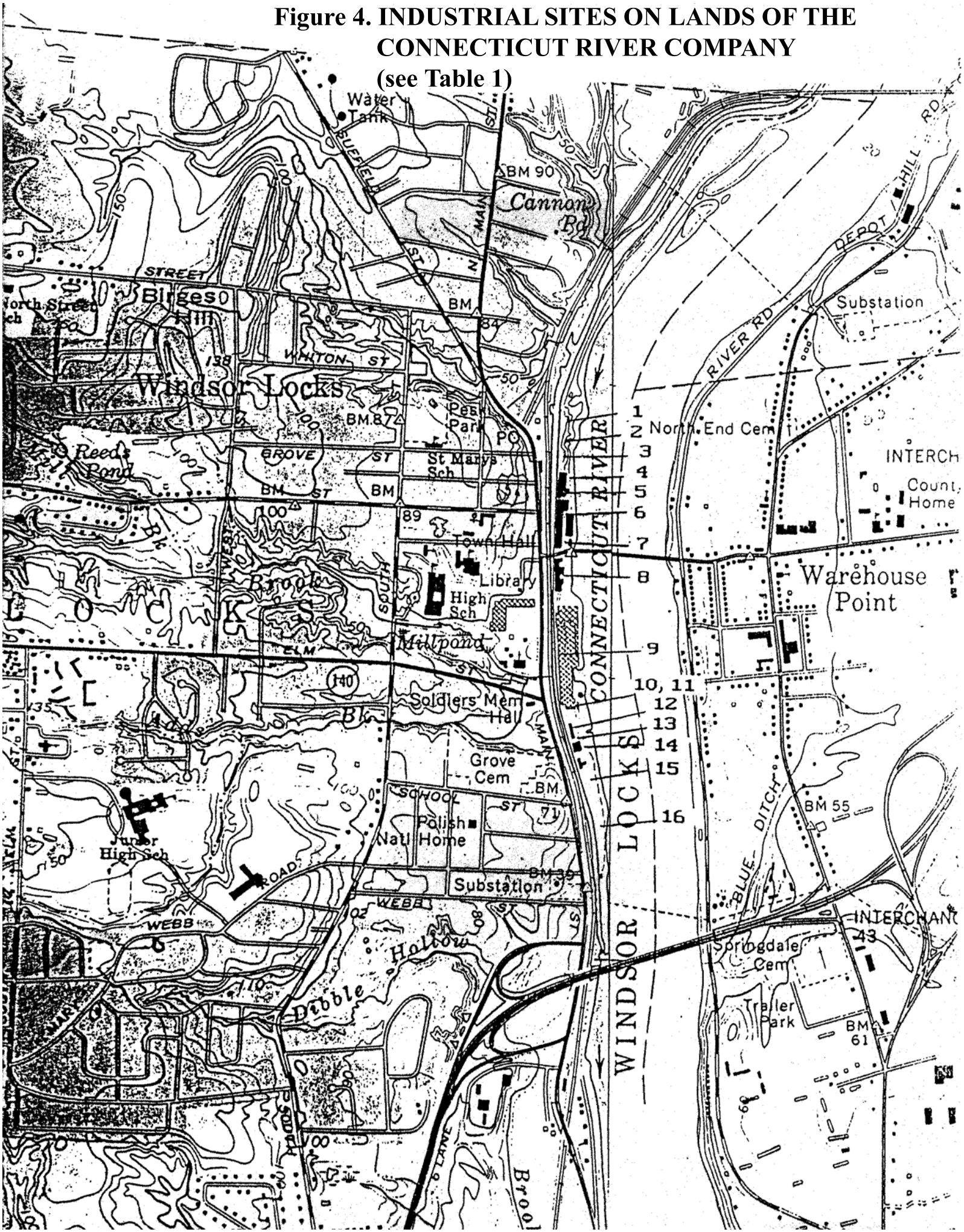

Table 1. HISTORIC INDUSTRIES LEASING LAND OR WATER FROM THE CONNECTICUT RIVER COMPANY

Time Periods

Site No.	Before c1845	c1845-1850	c1851-1855	c1851-1860	c1861-1865	c1866-1885	c1886-1900	c1901-1920	After c1920
1	A.P. Niles & Co., sawmill, 1836-c1840, with water lease & water lot; J.B. Chapman, sawmill, c1840-47	C.B. Hutchins & Co., sawmill, c1847-50	James Outterson, paper mill, c1850-55	Converse, Burbank & Co., manila paper mill (Atlantic Mill), c1856-57; sold to Persse & Brooks 1857, became part of Site No. 2.					
2				Persse & Brooks Pacific paper mill, with water lease, water & building lots, 1857-62	Seymour Paper Co. c1862-98		American Writing Paper Co. bought plant 1898, operated under its Windsor Paper Co. Division to 1930		paper plant closed 1930, later demolished
3						G. Glover & Son machine repairs c1870-80; G.Glover, Jr. & others built Windsor Locks Machine Co. plant for paper-making machinery; water lease, water & building lots, c1881-1920		plant burned & rebuilt 1903, enlarged 1907; site taken over by Windsor Paper Co. c1920, made part of Site No. 2	
4					H.A. Converse & Co moved from Site No 6b, built new foundry 1864; no water lease	plant enlarged 1867; became A.W. Converse & Co. c1882, operated to c1890	plant taken over by Eli Horton & Son c1890, as part of Site No. 5		
5					Eli Horton built patented lathe chucks in shops built 1865, with water lease, water & building lots; Horton began chuck development 1851, worked as master mechanic for Persse & Brooks and made chucks at Site No. 7, c1851-64	Incorporated 1873; Horton's son-in-law Ezra Bailey took over c1878 after E. Horton's death			1949 purchase of Gabb Manufacturing Co.; Gabb made aircraft products & production equipment in East Hartford; Horton Chuck Division operated with modernized plant, sold 1956 to Greenfield Tap & Die Co. by Conn. International, which ran Crouse-Hinds Co. here until 1981
6	Jonathan Danforth, door-butt factory, c1831-35, with water lease, water & building lots; cotton batting factory c1835-44 under various owners	Site divided c1844-64: 6a: Slate & Brown machine shop, cotton & other machinery, likely with 1831 water lease, in c1831 finishing building, c1844-50 6b: J.P. & H.A. Converse foundry in c1831 factory, with new water lease, water & building lots, 1844-60	6a: Denslow & Beach machine shop operations, F.M. Brown, cotton machinery 6b: H.A. Converse foundry	6a: A.G. West sewing machine manufactory; Denslow & Chase machine shop, c1860-64,	6a: probably site of William Muir Army rifle contract, 1863-64; 6b: H.A. Converse built new plant at Site No. 4, 1864; 6a & 6b combined 1864 under various wool-scouring firms, H.R. Coffin & Co. the earliest	Dwight, Skinner & Co. sold site to Montgomery Co. 1881, and purchased Seymour Paper Co. plant at Site No. 7; Montgomery made cotton & novelty yarns, used site, with expansion, to 1989; also see Site No. 16	plant expansion 1891-93	plant expansion 1904	
7	Samuel Williams & W.H, E.H., & S.O. Hollister paper mill, with water lease, c1833-44; many operator combinations	Persse & Brooks Anchor Mill in 1833 plant, with new water lease & water lot, 1844-56		Anchor Mill burned 1856, rebuilt 1857 & part of new Persse & Brooks Paper Works Co, c1857-62	Seymour Paper Co. lower mill, c1862-82	Dwight, Skinner & Co., wool scourers, bought plant 1882, moved from Site No. 6	Anchor Mill Paper Co. bought plant 1894, made copying, silver, & anti-tarnish tissue, impression copying books to c1920	Montgomery Co. bought & demolished site c1920, built concrete factory; consolidated all operations at Site Nos. 6 and 16;	principal site of Montgomery Co. tinsel manufacture for: electric, telephone, & radio cords; military braid; drawing & electroplating of tinsel wire after 1925; wire mesh products after c1938; metallic yarns after c1950; ran to 1989
8	James & John Wells paper mill, with water lease & water lot, c1839-43; operated by C.P. Hollister 1843-47	mill burned 1847; ruins bought by A. & G. Blake for cotton batting plant, with new water lease & water lot; plant sold to L.B. Chapman 1850	run as stockinet factory by varied tenants of L.B. Chapman, c1851-63		A.G. Medlicott & others began later Medlicott Co., c1863-1950; made cut stockinet good c1863-67, full-fashion knit underwear afterwards; site rebuilt & enlarged c1863-88	Plant expanded 1881, 1885, 1888; all operations at Site No. 11 consolidated here c1888; operated to c1950			
9	C.H. Dexter manila paper plant begun east of canal by 1840, probably with Kettle Brook water	C.H. Dexter & E.A. Douglass enlarged paper mill 1847, with water lease; still operating 1991; firm eventually the Dexter Corp., with earlier Dexter grist & saw mill			toilet paper products introduced 1861-62, made until 1936	Plant burned 1873, rebuilt; expanded 1881	new products 1886-95: tissues, Bristols, pattern paper, manifold linen; plant expanded 1898	heavy cover papers	discontinued heavy cover papers 1923; specialized in lightweight papers for condensers, typewriting, medical preparations, favors; plant expansions 1924, 1927, 1930, 1954, 1959, 1967; concentration on long-fiber paper products after c1935, including teabag paper, hospital products, other filters
10	Royal Prouty wire-drawing mill, c1839-57; water lease undocumented				Site area used as part of Site No. 11 by Medlicott Co., c1863-88 (see Site No. 8)				
11		Leander Hotchkiss edge tool & machine shop, c1847-49, no water lease; converted to Carroll & Risley paper mill, c1849-57 under several operators			Site area used by Medlicott Co. as secondary plant, c1863-88 (see Site No. 8)		Windsor Locks Electric Light Co. took over part of site 1893, with water lease; made hydroelectric power	Northern Connecticut Light & Power Co. bought Windsor Locks Electric c1907-08; generated power & distributed gas from Hartford	plant sold to C.H. Dexter Corp. 1942
							George P. Clark built plant for industrial trucks, casters, etc, on part of Site No. 11, 1893; no water, used gas & steam power; Clark first developed & marketed products while machinist & superintendent for Dwight, Skinner & Co. at Site No. 7 c1870-92	Firm incorporated as George P. Clark Co.; added power plant 1906; purchased Windsor Silk Co. at Site No. 13, 1913; plant rebuilt in concrete 1919-20	continued development of materials handling products
13	H. Haskell & Jabez Hayden gin mill, 1811-33; pre-dated canal, given perpetual water lease; converted to silk thread mill 1838, operated to 1913	mill burned & rebuilt 1848				Dwight Allen took over silk mill 1881, ran it to c1895	Gudbrod Bros. Co. sewing silk plant, c1895-1900	Windsor Silk Co. c1900-13; site sold to George P. Clark Co. (Site No. 12) & plant demolished c1919	
14		Josiah Rice plant for Wesson & Leavitt rifles, no water lease, c1845; undocumented others made cotton batting & twine, c1845-49; converted to thread & twine plant by Wilmarth Thread Co., with water lease & water lot, ran c1849-65			Used as Medlicott Co. subsidiary plant, c1865-78 (see Site No. 8)	converted to tissue paper plant by F.H. Whitlesey c1878, operated to c1915		Windsor Paper Co. plant c1925-30 (see Site No. 1)	
15		Philip & E.J. Ripley iron rolling mill, with water lease, c1845-50; Ripley & Talcott c1850-56		iron works leased to T.G. Noack c1856-7; enlarged as steel works by Farist & Windsor/Windsor Locks Steel Co., made crucible steel for dies & tools, & some steel products with purchased billets, c1860-95					
16		Connecticut River Co. rental factory c1846, leased to Connecticut River Mills for printing cloths & umbrella goods c1847-56		Austin Dunham & Co. bought mill c1856, used by various textile operations c1856-71		J.R. & George Montgomery leased Dunham mill 1871, made specialty cotton yarns & warps, novelty yarns beginning 1876, metal or tinsel yarns 1886; Montgomery Co. expanded yarn operations at Site No. 6 1881		developed tinsel products for telephones, electric products, military braid, decorative fabrics and ribbons; plant closed with 1920 expansion of Site No. 6	

SOURCES:

1. Maps: Woodford 1855
   Baker and Tilden 1869
   O.H. Bailey 1877
   Sanborn Map & Publishing Co. 1885b
   Sanborn-Perris Map Company Ltd. 1892, 1897
   Sanborn Map Company 1905b, 1912b, 1925
   Hughes and Bailey 1913
2. Drawings: C.H. Dexter Division 1977, 1979
3. Deeds: Windsor Deeds 32:277-9; 33:274-6; 34:288-90; 35:278-9; 37:4-5, 50-2, 85-91, 148-50, 175-7
   Windsor Locks Deeds 3:5-11, 89-96, 97-102, 482-9; 6:12-15, 301-4, 394-8, 407-09; 8:168-73, 362-66, 64-4; 9:165-9; 16:112-15, 129-34
4. Secondary: Stiles 1892, I:504-19
   Anonymous 1954, 1976
5. Manuscript: Shedd and Sarle 1912
   U.S. Census Bureau 1850-80

The Connecticut River Company did not engage in manufacturing, but attempted to attract entrepreneurs and industrial developers with 999-year leases of waterpower, "water lots" in the narrow strip east of the canal, and building lots west of the canal on which worker housing could be erected. The company also built a factory for lease at the lowermost site. To reduce the risk of fire in the increasingly dense row of industrial structures, the company first encouraged, and by c1834 required, buildings on its water lots over 10 feet high to have brick or stone walls, and generally prohibited fire-prone enterprises including distilleries, "offensive" chemical works, gunpowder plants, and potteries (e.g., Windsor Deeds 33: 274-6; Windsor Locks Deeds 3: 5-11). Not all firms began with Connecticut River Company leases, however. Two long-lived operations, the Dexter paper plant and the Haskell-Hayden silk thread factory, began with land and water rights acquired before canal construction, and subdivision of Dexter land rights evidently allowed several other firms to begin. A few firms apparently opened with no waterpower, but eventually acquired at least some water rights from the Connecticut River Company or earlier operations (Connecticut River Company 1856-69).

Even with filled extensions of the river bank, the industrial water lots inhibited the size of many mill complexes. Three of the larger operations -- the Persse and Brooks (later Seymour Paper), Medlicott, and Montgomery companies -- spent 25-40 years using two or three separate plants along the canal, until consolidations at single locations c1882-1920. Several other smaller firms with single plants changed locations as they grew. Space constrictions did not always prohibit large operations: Persse and Brooks was reputed to have the largest American paper plant in c1856, albeit covering three sites (Anonymous 1954: 19; Anonymous c1988: 20-1). Yet the generally small sites probably worked best with manufacturers of relatively small runs of highly specialized products. The most distinctive Windsor Locks industries, including most of those which lasted here after c1930, were specialty or niche producers. This concept is discussed below in section VII.B, as an introduction to examples of important local firms.

The combination of railroad and canal freighting available after 1844, and the Connecticut River Company's somewhat more aggressive approach to selling leases when canal traffic nearly disappeared, both contributed to the great increase in industrial activity. As noted in section V, the canal continued to bring coal to canal-side mills until the very late 19th century. It is also likely that the growth of the machine tool industry and the population of skilled mechanicians in New England was an important factor in the success of many Windsor Locks firms. The larger mills created not only a demand for equipment which encouraged local machine shop development, but a constant need for skills needed to repair and maintain machines, and to modify equipment for incremental changes needed to sustain specialty production. Several of Windsor Locks' most important mechanics, notably Eli Horton and George P. Clark, worked as senior machinists or superintendents of large paper and textile mills before opening their own shops (Anonymous 1931; Anonymous 1954: 59, 64).

3. Later Industries Off the Canal

Some of the same factors which encouraged Windsor Locks Canal industries -- better transportation and more developed mechanical technologies -- allowed other local waterpowered industries to develop away from the canal. At the former Dexter fulling mill site on Kettle Brook, the Holbrook family made school supplies c1860-1919. The c1781 Pine Meadow Brook grist mill site followed a pattern not unlike some canal-side locations, evolving into a wool-carding and paper mill beginning c1860. The growth of local industries, and of the housing which accompanied this growth, led to more demand for lumber and hardware. By the 1870s, H.C. Douglas had a lumber business on North Main Street in Windsor Locks, which passed by 1888 to Frederick S. Bidwell. Bidwell established the first of several hardware stores run by his firm on Main Street in 1890, and in 1892 began a lumber yard nearer the center of town, on wet or poorly drained land west of the Seymour Paper Company's plant. Bidwell used ashes from the paper plant to fill these sites, expanding his operations several times and operating well into the 20th century as F.S. Bidwell & Co. (Stiles 1892, I: 509, 515; Anonymous 1954: 11, 71-2).

In Enfield, Scantic River and Freshwater Brook powered mill villages at, respectively, Hazardville (gunpowder) and Thompsonville (carpets) by c1840, and several textile mills developed in sections of East Windsor (Tarbox 1886; Winch 1886). The evolving carpet firms at Thompsonville became the third largest textile firm in New England by 1914 (Roth et al. 1981: 37). Local sandstone quarrying, practiced until recently near the canal, probably began commercially with canal construction and persisted on both sides of the river, with several quarries owned by the Connecticut River Company (Stiles 1892, I: 554).

B. Flexible Manufacture, Niche/Batch Production, and Incremental Innovation

Most of the industries that flourished in Windsor Locks were those that excelled at niche or batch production, not the manufacture of standard, mass-produced staple goods. The successful firms were often highly flexible and capable of adopting quickly to market changes and new opportunities. While bulk paper makers relied on rags or wood pulp as basic materials, C. H. Dexter saw the potential for a strong manilla paper made from hemp. The Nonwovens Division of Dexter today has found profitable market niches with filter paper for tea bags and special coverings for sausages. In the case of J. R. Montgomery, we have a manufacturer who moved into novelty yarns because he saw the growing demand for relatively high cost yarns from abroad and believed that he could make similar goods more cheaply in America. He also introduced Mercerized cotton technology in this country and helped to create new domestic markets for cotton yarns with a silk-like lustre. The many tinsel materials that the Montgomery Company produced up to the 1980s are wonderful examples of batch production and creative responses to customers' needs. A company has to be flexible to operate simultaneously to blend textile and metal technologies as well as Montgomery did.

What Philip Scranton has called "a format centered on timely, specialized batch production" may be the key to much of Connecticut's industrial success in the nineteenth and early 20th centuries. The same may be said of manufacturing in general; mass production of standardized products was not characteristic of American industry as a whole. We now have the possibility of revitalizing the American economy by once again stressing flexibility. It is important for us to understand how flexible manufacturing worked in places like Windsor Locks, and what problems its practitioners faced. The networking and interdependence of batch firms is particularly interesting and instructive (Scranton 1989a: 1-2, 8-10, 13; Roth et al. 1981: xvi-xvii).

Constant change and technological adaptation was particularly important in plants that made a large number of products and needed to satisfy fickle customers or clients. The astounding amount of individual machine and production system modification that took place in many American factories (such as the J. R. Montgomery Company) has largely escaped the attention of historians. The written history of manufacturing technology has tended to focus only on the exceptional machine innovations and, to a lesser extent, system developments that had a major impact on industrial production. In so doing, it has almost entirely ignored the incremental changes that may be, in their cumulative effects, much more important (Rosenberg 1976: 292; Malone 1988: 63-5). Documentary descriptions and engineering drawings of small modifications in machinery or technical processes were less likely to be saved than the records of major inventions. This type of innovation, much of which was generated by workers on the shop floor, was so common in many industries that it received little notice in business documents. Only a tiny fraction of these modest improvements were ever patented; most were made directly from the mental conceptions of their inventors without resort to drafting of technical drawings or writing of specifications (Ferguson 1977: 827-836). There were, in fact, few patents from Windsor Locks in the nineteenth century; Eli Horton's patents are among the few exceptions, and they are generally incremental in nature.

In 1963, Nathan Rosenberg called attention to the stultifying effects of what he labeled "Schumpeterian blight," the prevailing historical emphasis on technological leadership and on "the more dramatic and discontinuous aspects of innovation." He urged historians to study "the cumulative impact of relatively small innovations (which were of great importance in the design, development, and adaptation of machines)." Rosenberg has since praised those who see the normal pattern of technological progress as "steady accretion of innumerable minor improvements and modifications, with only very infrequent major innovations" (Rosenberg 1976: 292n; Rosenberg 1982: 6-7).

Recently, Scranton noted the importance of Rosenberg's insights for labor historians and bemoaned the continuing lack of scholarship on the technical development that takes place on the shop floor: "The history of workers' roles in incremental technical change remains as opaque today as the general history of the workplace was two decades ago (Scranton 1989b: 10). Scranton is a textile historian who has seen the overwhelming evidence of both evolutionary change and responsive technical creativity in the mills of Philadelphia (1983, 1989a). There is similar pattern in Windsor Locks, particularly at the J. R. Montgomery Company where workers continually modified textile twisting machines and tinsel production equipment, and where in-house innovation was necessary for the company's many moves into new technology (Anonymous c1971; personal communications, Spencer Montgomery, Jr., and Robert Brengi).

C. Growth and Significance of Selected Industrial Firms

The great majority of the industrial firms which operated in or near the proposed park remain poorly documented in the sources reviewed for this report. Among those firms for which we have better information, we have selected some examples which reflect the distinctive qualities and products of local industry. All these examples are on the canal in Windsor Locks, and retain much of their historic plant environment.

1. C.H. Dexter and Successors

The Dexter Corporation, whose historic home is now the firm's Nonwovens Division plant south of Route 140 (Table 1: Site 9), is the most historically significant of the town's surviving industries. It is the oldest firm in the area, and has been making paper products on the canal for over 140 years; the corporation traces its earliest roots over 220 years, to the 1767-84 fulling, grist, and saw mills begun by the Dexter and Haskell families on Kettle Brook. The Windsor Locks paper plant has never been especially large, but as discussed above its products have been extremely specialized. Relatively small runs of high-quality hemp- and wood-based paper items have secured important market niches, including products which few competitors could make.

The firm's general history is well-documented (Stiles 1982, I and II; Anonymous 1954; Coffin 1967; Anonymous c1988; Osborne n.d.). The Seth Dexter II family arrived in Pine Meadow c1767 from Rochester, Massachusetts, along with their in-laws in the Jabez Haskell (c1746-1816) family. With the 160 acres and mill rights purchased by their fathers, the two men became prominent local industrialists. The Haskells, more heavily involved in their gin distillery after 1811, ceded full control of the grist and saw mill to Seth Dexter III (1776-1841) after the latter sold the Dexter fulling mill in 1817. Seth III built a second gristmill, west of the later canal, in 1819. The Haskells finally sold their remaining interests in 1837 to Seth III's son Charles Haskell Dexter (1810-69) and Seth's daughter's husband Edwin A. Douglas (1804-59), the probable superintendent of Enfield Canal construction. By 1837, the Haskells were about to re-use their distillery as a silk thread mill, with Jabez Hayden, and C.H. Dexter had begun production of manila wrapping paper in the grist mill basement. Dexter and Douglas began commercial paper production c1840, building a frame mill east of the canal. This mill may have initially been hand-operated, until an 1847 expansion which included water-powered equipment.[1] The operation became C.H. Dexter & Co. at this time. Douglas, who lived in New Jersey and Pennsylvania by c1830, sold out to Dexter in 1856.

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[1] There is no record of Dexter and Douglas purchasing water rights from the Connecticut River Company before 1849 (Windsor Locks Deeds 16: 129-31). Although located along the path of Kettle Brook, which was carried under the canal in a culvert, the paper mill was probably too far downstream to tap the brook for power with the canal in the way. The absence to date of any documented Fourdrinier equipment in the mill before c1847, and the small output of about 200 pounds of paper/day, suggest the earlier absence of water or steam power.

C.H. Dexter's origins as a papermaker remain somewhat mysterious, since there is no documented evidence of his involvement in this trade prior to his earliest experiments at the grist mill in 1836. According to one local chronicle,

> "He was the first to make paper out of bagging, and for several years purchased saltpetre bags from Col. Hazard, the powder manufacturer of Hazardville, and converted them to paper. He was also the first to discover and utilize the use of lime in cooking and preparing stock, as it killed the germs in the fibres" (Stiles 1892, I: 510).

He may have been influenced by the Franklin and Eagle mills in Suffield, or by the first paper mill opened on the canal in 1833 (Table 1: Site 7), but why he chose to work with manila hemp is not clear. Contemporary experimental work on using hemp and other non-wood vegetable materials for paper may have encouraged Dexter (Singh 1991). The Dexter firm made a variety of manila and wood paper products in the 1847 mill, including Medicated Star Mills Water Closet Paper introduced during the Civil War; toilet paper remained a Dexter product until 1936. Two years before his death in 1869, C.H. Dexter organized the firm as C.H. Dexter & Sons, with son Edwin (1847-1886) and sons-in-law Herbert R. Coffin (1840-1901) and Bennett Allen.

Allen soon left the firm, leaving Edwin Dexter and Coffin to run the firm together until Dexter's death in 1886.[1] During this period, they enlarged the paper mill in 1869 and 1872, tripling its output to about 4600 pounds/day with new equipment, and then had to rebuild it with an iron-framed, brick clad plant after an 1873 fire. The present plant, with a variety of brick, concrete, and all-metal structures, originates with the 1875 replacement mill. The firm again expanded its equipment in 1881, including an 88-inch Fourdrinier machine with which high-grade white copying and colored French tissues could be made. After Edwin Dexter's death, H.R. Coffin oversaw the introduction of new tissue and wrapping papers made from manila and linen, and a generation of high-quality, heavy manila cover papers made c1887-1923. Under Coffin, the plant was enlarged in 1898, to a daily output capability of fourteen tons. Soon after his death, his sons Herbert, Jr. (1871-1938) and Arthur D. (1868-1940) increased production again by buying the Franklin Mill in Suffield, which the firm had leased after the 1873 Dexter mill fire. In 1914, when the Franklin mills burned for the last time, the Dexter brother incorporated the partnership as C.H. Dexter & Sons, Inc., with A.D. Coffin as President. Until very recently, direction of the firm passed within A.D. Coffin's immediate family, to his son Dexter D. (1898-1966, president 1936-58) and his grandson David L. (b. 1925, president 1958-90).

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[1] They also continued to operate the saw and grist mill, along with the store begun in 1784 by Seth Dexter II and Jabez Haskell near the ferry. The first grist mill, east of the canal, became a paper plant storeroom until its demolition in 1898; the 1819 grist mill survived west of the canal until 1925 (Anonymous 1954: 11, 57).

After the heavyweight covers were discontinued in 1923, production focussed on short-fiber, lightweight carbon, condenser, and tissue papers until the late 1930s. New mill additions in 1924 and 1927 accommodated expanded manufacture of the lightweight papers. Although some of the short-fiber products were made until 1947, by 1935 Fay Osborne's success with long-fiber, hemp-based papers re-directed Dexter efforts into a wide range of new products, as discussed above, which grew to include teabags, electrolytic condensers, meat casing, diapers, lens tissue, and other absorbent or filter papers. During a period of security provided by Osborne's 1936 patent for making long-fiber paper, C.H. Dexter & Sons added two new paper machines in a 1954 addition, and additional power, pulp mill, and paper making facilities in a second large addition built 1959-62. The firm also began to diversify after 1957 into related specialty chemical material areas, taking over some firms with established industrial markets. To maintain its established edge in specialty products as the patent protection ended early in the 1960s, the firm enlarged its research and development facilities, and re-incorporated as the Dexter Corporation in 1966, in which the original plant became one of four divisions. The most recent plant expansion in Windsor Locks was a 1967 addition plus warehouse to house the world's largest long-fiber paper machine, which increased plant capacity by 40%.

Most of the plant built after 1873 survives, with many modifications and different building technologies reflecting the long evolution of this firm. No detailed historic study of these structures has ever been done.

2. Eli Horton and Successors

Beginning in 1840, Eli Horton worked in the West Stafford, CT. shop of one of the first makers of universal chucks, Simon Fairman (Anon. 1954: 59). Chucks were mechanisms for holding workpieces in machines such as lathes. The universal type had multiple jaws which could all be closed at the same time and to the same extent. They can be contrasted with independent chucks, which required the operator to adjust each jaw separately. This independent action could be an advantage with irregular workpieces but was a bothersome chore much of the time.

The universal chuck evolved over time, improved by various machinist/inventors and developed in numerous forms. Eli Horton patented his "new and useful Improvements in Lathe Chucks" in 1855 (Patent #13787). He claimed as original several features of its universal closing mechanism as well as its capability to protect the critical circular rack from chips and filings. Moving to Windsor Locks in about 1851, he at first worked as a machinist in the Persse and Brooks paper mill. In 1865, he set up his own water-powered shop, specializing in universal lathe chucks. Among the many types of Horton chucks were large versions for railway car wheels. He made his chucks with 2, 3, or 4 jaws, and entered them in a number of international exhibitions, where they were very well-received (Anonymous 1931; Anonymous 1954: 59-60; American Machinist 1881).

At the Vienna Exhibition in 1873, the official report by American engineer Robert Thurston devoted special attention to "...a neat little device...": the Horton lathe chuck. Horton apparently won an award with his well-made chuck, which could function as either a univeral or an "excellent independent jaw-chuck." The British expert J. Anderson thought that the American chucks were the best in the exhibition (Thurston 1875: 337; Steed 1969: 91; Anon. 1954: 59-60).

Although there were many chuck manufacturers in Connecticut, the rugged simplicity of Horton's designs and the gradual improvements in their construction kept them popular over the years. Eli Horton got another patent in 1873, for an "improvement in chucks (Patent # 142,163)." It is a classic of incremental innovation. His small but nevertheless significant improvement was primarily in finding a way to grind the case-hardened jaws of his chucks perfectly true. He simply added small grooves that allowed machinists to use a vitreous emery wheel, a recent development for precision grinding, on the stepped faces of the jaws. This was an ingenious way to solve the problem of slight deformation as a result of the case-hardening process. Scientific American thought it was important enough to print a brief article and illustration on Horton's improvement (Anonymous 1873). It is unclear, however, if Horton actually applied this innovation to his commercial products.

Another Windsor Locks inventor, less well known and apparently far less successful than Eli Horton, got a patent for a planer chuck in 1868 (Patent # 78,132). Charles Riggs hoped to find his own niche with a product similar in some ways to Horton's but designed for a different type of machine tool.

Eli Horton died in 1878, but other members of his family carried on the business. By the end of the 19th century, they were making drill chucks and other milling devices (E. Horton & Sons 1896-1941). The fine reputation of the Horton chuck is suggested in the best machine shop guide of the nineteenth-century, Joshua Rose's Modern Machine Shop Practice, which has detailed descriptions and illustrations of Horton products (Rose 1888,I: 234-241). Perhaps the most telling indication of the firm's accomplishments is that they were able to sell products with few known alterations for many years, probably until about World War II (E. Horton & Sons Company 1896-1941). Modern chucks are generally made of steel and are lighter than Horton's iron, steel-jawed devices. We do not at present know if the Horton firm changed its manufacturing methods or materials over the years, although the c1890 acquisition of the H.A. Converse foundry at an adjacent canal site suggests they had the capability to use a wide variety of metals.

E. Horton and Son Company underwent a managerial change in 1948 and a modernization of the physical plant. It purchased Gabb Manufacturing in 1949, and established Horton Chuck and Gabb Special Products divisions. Cooper Industries' Connecticut International Division bought the Horton firm c1956, and sold the Horton Chuck Division to Greenfield Tap and Die Company. This sale ended chuck manufacture in Windsor Locks. Connecticut International, a producer of aviation lighting, absorbed Gabb and operated its Crouse-Hinds Company here until c1981, when it moved all operations out of Windsor Locks. The J.R. Montgomery Company then bought the site (Anonymous 1976; Ransom 1979; personal communication, William Fitzpatrick). Montgomery has since gone out of business.

The National Register nomination for the combined Montgomery/Horton complex provides detailed information on the buildings. "Building A South" was constructed by Eli Horton in 1864-1865 to house his chuck company (Ransom 1989). With this lot, he got his first lease of water (100 square inches) from the Connecticut River Company in 1865 (Windsor Locks Deed Books 6: 12-15). Building A is the oldest structure in the complex, and is significant not only for its brick mill architecture but also for its association with the famous chuck maker. It is also apparently the oldest surviving industrial structure on the Windsor Locks Canal.

3. J.R. Montgomery Company Novelty Yarns - J.R. Montgomery Company

In 1871, J. R. Montgomery came to Windsor Locks from Massachusetts to spin and sell cotton yarns. He rented the cotton factory of the Connecticut River Company near the Lower Locks for this purpose. Soon his company was a major supplier of cotton warps to various cotton and woolen weaving mills. In addition to spinning warps, he moved into dyeing and finishing. His next step was a critical one: he and his brother, George M., began to make novelty yarns (Anonymous 1954: 60-63; Anonymous 1893; personal communications, Spencer Montgomery, Jr., and Robert Brengi)

George M. Montgomery, president of the J. R. Montgomery Company, defined novelty yarns in an address to the New England Cotton Textile Manufacturers' Association (G. Montgomery 1904: 196). He said the term included "all yarns which are used to give an unusual or novel effect in fabrics or trimmings." Often these yarns combined plies of different color or material. The plies were twisted together to produce a wide variety of color patterns and surface textures. Textile machines (usually twisters with special attachments or alterations) could create spirals, loops, flakes, knots, or nubs in yarn. A booklet on fancy (novelty) yarn twisters from the Whitin Machine Works said that "...the almost limitless numbers of patterns, varying according to the dictates of fashion, are sometimes intricate in finish and always colorful in appearance..." (Whitin 1949-1950: 2,4-5). Textile directories confirm the heavy reliance on twisters by Montgomery (Blue Book 1888-1980).

The J. R. Montgomery Company was one of the first American firms to produce and market a broad selection of novelty yarns. The Windsor Locks company, which had been concentrating on cotton warps, got into this business in 1876, after an imported dress fabric spurred a sudden demand for what was called "bourette," a type of knotted worsted yarn. George Montgomery (1904: 197) said that "The American manufacturer, as was his custom in those days, quickly set about to imitate the goods in a lower grade." After experimenting with and improving machinery, the J. R. Montgomery Company was apparently able to match the quality of many imported novelty yarns and came up with many new products of their own. In one case, the firm used an experimental machine to wrap expensive worsted fibers around a cotton thread, thus simulating worsted yarns at a reasonable price. When imported "boucle yarn," distinguished by exposed loops of mohair, became the rage in 1883, "it was necessary to build new and adapt old" machinery to mass produce this popular yarn in America (George Montgomery 1904: 198-199).

The Montgomery Company's thousands of novelty yarn products over the years reflect the constant shifts and variations of textile fashions.

The firm's ability to produce so many different yarns is evidence of the incremental innovation and machine modification that was essential in textile companies who responded to, or stimulated, changing markets (Scranton 1989a: 1-16). This is a superb example of niche production and flexible manufacturing.

As the company expanded in the 1870s, it needed more room for manufacturing its specialty products and more power as well. In 1881, J.R. Montgomery moved the novelty yarn operations to a site with additional power further north, which he purchased from H. C. Dwight. Cotton warp production remained at the lower site. Montgomery expanded in the 1890s at the northern site and took over lands adjacent to it in the twentieth century.

Another example of J. R. Montgomery's pioneering role in textile manufacturing was his introduction of Mercerized cotton technology in the United States. This process, originally developed in England and improved in Germany, put a luster on cotton yarns and simultaneously increased both their strength and their affinity for dyes. In 1898, J. R. Montgomery delivered a paper to the New England Association of Cotton Manufacturer's association on his recent success with the new process. Mercerized cottons soon became very popular in this country and one of Montgomery's major products into the 1920s (J.R. Montgomery 1898: 134-152).

In 1886 the warp and novelty yarn manufacturer also began to make tinsel and tinsel yarns, a subtype of novelty yarns. Tinsel was defined in 1900 as a "term long used to denote a glittering metallic substance, as burnished brass, copper or tin, made in sheets approaching the thinness of foil, and used in strips or threads for any purpose in which a sparkling effect is desired without much cost (Cole 1900:550)." Montgomery bought drawn copper wire, often coated with gold or silver, and then flattened the wire to produce tinsel, which could then be wound around a textile base. Initially the major uses for these lame' tinsel yarns were in decorative dress fabrics. From novelty tinsel for dress fabrics, military uniforms, and drapery brocade, the company moved into "copper tinsel thread" for telephone cords. In the first decade of the twentieth century, Montgomery worked with American Brass in Waterbury to develop a type of phosphor bronze alloy that has had lasting value because of its resistance to metal fatigue. By about 1925, the company was doing its own drawing of wire using complex machinery and diamond dies and its own electro-plating. The conducting tinsel was at first the phosphor bronze alloy, wrapped tightly around a textile core (cotton or later nylon). Later, a number of these threads were grouped together, insulated, and encased with a braided textile fabric covering. The company claimed to be the only supplier of this cord for the telephone industry after WWI, because no other firm could wrap the metal tinsel tightly enough around the textile core . Until its 1989 closing, the Montgomery Company still supplied tinsel for the flexible cords used with telephone handsets (Anonymous 1954: 60-62; Anonymous c1971; personal communications, Spencer Montgomery, Jr., and Robert Brengi).

The company in 1919 was advertising in cotton trade publications that it made gold, silver, and copper tinsel on spools; tinsel threads of various types; tinsel metal cords 'for tying candy boxes and Chrismas packages;" and two or three ply tinsel "brilliants (Standard Cotton Mill Practice 1919: 135)" Following the company in textiledirectories, we also see tinsel mop yarns, tinsel lame, and tinsel conductors in 1930 (Davison 1930: 216); conductor and resistance tinsel cordage, lame', and laminettas in 1950; fine wire, knitted metal mesh, and curled wire in 1970 (Blue Book 1930: 216, 1950: 195, 1970: 53. By the 1940s, the company stopped making textile yarns it had been purchasing much of its yarn since at least 1930) and was concentrating on electrical and other tinsels, many of which have already been noted listed above. Montgomery tinsels and tinsel yarns went into thousands of consumer and military products. There were applications of its conductors in radios and telephones, shavers, electric toothbrushes, cardiac pacemakers, hearing aids, dictating machines, radar components, computers, and the heating elements of WWII flight suits and electric blankets. Much of the gold "braid" for United States Navy uniforms was woven from Montgomery tinsel yarns and threads. The company even made tinsel suitable for production of pot scrubbers and filter mesh (ibid.).

Much of the northern plant of the Montgomery Company, direct descendant of the J. H. Montgomery Company, remains in Windsor Locks, despite the closing of all operations in the community after a corporate restructuring in 1989 that ended the long and proud history of the original firm. A detailed nomination for the National Register of Historic Places covers the physical history of the plant in some detail (Ransom 1989). A number of the brick structures and the reinforced concrete mill of 1920 north of the highway bridge are historically significant. At the Museum of American Textile History in North Andover, MA., there are also three insurance drawings of earlier Montgomery mills as they were in the 1870s and 1880s, including one of the cotton mill at the lower privilege that J. R. Montgomery originally leased from the Connecticut River Company (Barlow's Insurance Surveys 1875-81. None of the buildings in the drawings have survived.

VIII. COMMUNITY DEVELOPMENT

The two towns in the proposed park area have very different histories of development, and very different relationships with the river and the canal. Suffield was primarily an agricultural community until World War II, with a small industrial sector of firms using the local streams as power sources. Some individual families or neighborhoods near the river fished, made boats, or used resources on King's Island. A few people lived on the island, notably the Terry family who hosted a Millerite Second Advent event in 1873 (Ball 1944. Suffield settlement patterns and historic activities were, however, more oriented to the rich lacustrine soils and marshes west of the river, which for most residents was probably something to cross rather than use. The town developed around a dispersed network of roads, centered on a spectacular green or common. There was never any use of Windsor Locks Canal water for power in this town, and, with the road and rail networks available, probably local little use of the canal for transportation. After its early settlement, Suffield grew with rela-tively little connection to the river or the canal, except in the most basic senses of geography and soil origins.

As discussed above (section VII.A), Suffield had a long history of small industries, a few of which persisted into the early 20th century. They did not employ many people, and tobacco cultivation remained the major local enterprise for at least 140 years, beginning c1810 after at least a half century of increasing importance. Family farms apparently remained relatively stable in number, size, and occupation for much of this period. Over 90% of Suffield farms grew at least some tobacco c1850-70,and probably for some decades there-after Sheldon 1886: 402-4). Late in the 19th century, Polish immigrants arrived and eventually established a significant Polish community which joined the tobacco-raising culture; many Poles achieved farm ownership. Suffield's largely agrarian cast, reflected in a landscape dominated by tobacco barns and farmer and merchant homes, contributed to a frequently conservative approach to obtrusive new developments (Sheldon 1879, 1886; Alcorn 1970). The initial rejection of a railroad line through the town, and opposition to interstate highway routing over a century later, are more obvious affirmations of self-conscious agrarian stability (personal communication, Lester Smith). Expanding suburban settlement, fol-lowing on the heels of the decline of tobacco, has attenuated but not removed the town's rural character.

Windsor Locks, even in its Colonial infancy,was as much a small industrial center as an agricultural one. Soil conditions limited agricultural development by Windsor residents, or people like the Dexters and Haskells who moved here from Massachusetts. There are some close ties between Colonial families running small mills and later canal mill operators. Prior to canal construction, Pine Meadow was at best a hamlet. Windsor common lands, divided in 1752, covered the entire area west of Center Street, opened in that year. There was no significant settlement on the former commons until 1945. Public roads to the east remained limited to access routes for the 1784 ferry and the sawmill on Kettle Brook until 1815, when the river road (later Main Street) was established somewhat reluctantly by Windsor. The 1815 road served most of the local industries, and soon encouraged development of several inns.

Only after 1845 did population and settlement increase significantly, during the rapid of localized growth of Windsor Locks as an industrial community. Town settlement strongly reflects its close ties to the canal, without which it would still probably be part of Windsor. Superimposed on some early roads, a dense street grid extends back from the river, typical of river communities. A primarily industrial population lived here until recent decades, with a very large percentage of families involved with the canal mills as workers and managers. Since World War II, growth of Bradley Field/International Airport and the arrival of some new industries at the west end of town have changed the 19th-century industrial settlement pattern.

Irish immigrants were the earliest non-English Europeans to arrive at the start of the local industrial period, followed by some French-Canadians after the Civil War, and larger numbers of Italians and Poles after c1880. Virtually all these newcomers depended on industrial employment. Emerging ethnic and class diversity was reflected in the built environment of rectilinear streets extending over a half mile west, around Kettle and Add's brooks, from the canal factories. Mill owners lived in large colonial homes, or built new ones, along Elm, Center, and Main streets. Single- and some multiple-family worker homes were concentrated from Church Street north, closer to the largest 19th-century employer at the Persse & Brooks/Seymour paper plant. Some of the larger firms built housing for families or unmarried men, reflecting a paternalistic local control which occasionally took spectacular form, such as the 1869 erection of the stone Memorial Hall on Main Street by the Medlicott Company's Charles Chaffee. The town's persistent industrial character survived until the recent past, and is still reflected in much of the local housing stock. The commercial core of the town, on Main Street opposite the canal factories, has not survived urban renewal, but the Horton, northern Montgomery, and Dexter industrial structures remain to suggest the former mile-long "wall" of mills fronting the river.

IX. THE CONNECTICUT AS AN AMERICAN RIVER

The Connecticut is the longest river in New England and one of the most beautiful streams in America. The hydrological characteristics, geographical setting, and historical utilization of the river have been discussed in earlier chapters, but it is important to put the Connecticut in a national context, to look at it in comparison with other rivers in the United States.

The size of the Connecticut, so impressive by New England standards, does not compare that of the Mississippi or its larger tributaries. Many streams are longer, or wider, or more powerful. "The Long Tidal River" cannot match the Hudson's extended estuary. Its power potential is dwarfed by the short Niagara River draining most of the Great Lakes over a giant cataract, and by dozens of other rivers that today supply large amounts of hydroelectricity to regional customers.

The Connecticut's quantifiable characteristics are not exceptional, but subjective assessments of its handsome appearance fill the literature of travel and natural history. Timothy Dwight, a former president of Yale, was only exaggerating a little when he said that "This stream may, with more propriety than any other in the world, be named THE BEAUTIFUL RIVER." (Dwight in Delaney 1983: 9) Although urban, suburban, agricultural, and industrial development has not always been kind to the river and its banks, the beauty of the Connecticut persists. Long stretches of the river have changed very little in centuries, while other areas, altered by earlier generations of New Englanders, have returned to a surprisingly natural state. The "hand of man" has left a few eyesores along the river, but there are also structures and farmlands that please the eye and stimulate our historical imagination. Edmund Delaney's The Connecticut River (1983) and Ben Bachman's evocative Upstream: A Voyage on the Connecticut River (1985) provide ample evidence that the special charms and aesthetic delights of this historic river still deserve national recognition.

Roger Tory Peterson, the great naturalist, talks about the things we have done to American rivers and the options we have for conserving them. His discussion leaves little doubt about the lasting value of the Connecticut:

> A river has many faces and can be made to serve many purposes. You can drink it or bathe in it; use its surface as a highway for cargo carriers or pleasure craft; dam it for flood control or irrigation or power; cross it with bridges or let it remain as barrier to land travel; pollute it with sewage, chemical runoff, and industrial waste or preserve it in life-giving ecological balance. And if the river is as varied and beautiful as the Connecticut, you can merely look at it - in the long light of a sultry summer evening, under an angry winter sky, in the high color of autumn or the pastel shades of spring - and derive a sense of peace and uplift of the spirit that most men find in living water (Peterson in Hill 1972: 9)

Unfortunately, few of the present communities on the Connecticut take advantage of its appeal. Most seem to turn their backs on the river or to distance themselves from its banks. There is, of course, a justifiable fear of flooding and of ice flows. And in some communities like Windsor Locks, riverside property was industrialized at a relatively early date. Mills created walls of masonry that hid

the water from view and prevented ready access. Railroad lines were laid between the commercial districts and the water. The precipitous decline in the importance of waterborne transportation in the late nineteenth-century led to the disappearance of working waterfronts and the loss of "rivertown" identity.

The situation is now changing, however, particularly on the lower Connecticut (from Middletown to Saybrook) where appreciation of boating and riverfront amenities is on the rise. Throughout the nation, communities are re-evaluating their relationship with rivers. The San Antonio River Walk, begun in the 1930s and improved in the 1960s, has become an inspiration for city planners and riverfront enthusiasts. Providence, Rhode Island, has just stripped off the wide bridges that hid large sections of its rivers and is building a new urban center around the open waterways. Even Cleveland, Ohio, once famous for its flammable Cuyahoga River, now offers river cruises and a vibrant entertainment/restaurant district along the cleaned-up waterway (Little 1990: 81-91).

Human use of the Connecticut river has so far occupied only a brief moment in geological time. Yet for comparative purposes the historical utilization of the river is a fruitful area of inquiry. As the sections of this report indicate, this river of exceptional beauty is also a river of exceptional history. The historical significance of the river is perhaps most apparent in the early transportation developments that made the river navigable.

The newly-formed United States was rich in river resources, but natural waterways often presented serious difficulties for boats and rafts. The canals built between 1792 and 1810 to bypass five falls on the upper Connecticut River were early products of a growing demand for navigation improvements on internal waterways. Constructed by private companies with little coordination and no overall planning, the five river canals had locks of varying size. Their dimensional limitations and private ownership probably hindered the development of an effective navigation system on the river. Nevertheless, they helped to demonstrate that most river obstacles were not impassable barriers. In one case, the technology developed for an early Connecticut river canal had lasting value: the water-powered inclined plane built at South Hadley in 1793-94 was apparently the first such device used in this country (Shaw 1990: 9). Inclined planes later became important features on a number of canals, including the famous Morris Canal in New Jersey, which had thirty-three of them (Whitford 1906, II: 1374-1375).

The Merrimack River also had early canals around falls and steep rapids. The river's first historian, J. W. Meader, called the mile long Amoskeag Canal, begun in 1796 and completed in 1807, "a stupendous undertaking for that early period" and "one of the earliest internal improvements of magnitude in the country." The Middlesex Canal Company stepped in to upgrade the northern canals and to systematize their operation by 1815 (Meader 1869: 183-4, 208-209). The Middlesex Canal (completed in 1804) ran directly from the Merrimack River to Boston harbor. It took most of the river traffic away from the Pawtucket Canal, completed around the falls of the same name at North Chelmsford (later to become Lowell) in 1796. However, the Pawtucket Canal became the main feeder of Lowell's great water power system in 1823 (Malone 1983: 1-2).

Other pioneering efforts to improve river navigation took place on the Potomac, the Schuylkill, the lower Susquehanna, and the Mohawk (Shaw 1990: 3-11). By the 1830s, many American rivers had channel improvements and occasional bypass canals around falls; some had dams that created long sections of slackwater pools. However, there were still rapids and shoals that made long distance navigation seasonal at best on some major rivers. These natural obstructions were particularly troublesome for steamboat pilots on western rivers. Special steamboat types evolved to handle the strong currents and shallow, muddy streams common in the midwest, west, and south. These light, flat-bottomed vessels had high pressure engines, often combined with stern paddle wheels. Typical eastern steamboats, which usually operated in coastal waters or deep rivers, had sharper, ship-like hulls and low-pressure engines (Hunter 1949).

The first American canal with locks specifically designed to handle steamboat traffic was the Enfield, or Windsor Locks, Canal. When the Connecticut River Company opened this canal in November, 1829, and Thomas Blanchard's steamboat *Vermont* passed through it, the directors were looking ahead to the expected growth of steamboat traffic on the upper river. However, the company could not afford to purchase and rebuild the smaller canals at upstream falls. Even the canal at Windsor Locks could only handle very small steamboats; to run upstream from Hartford and through the canal, boats had to have very narrow dimensions and shallow water capabilities almost as impressive as western steamboats. The dreams of steady steamboat traffic faded quickly, and water power leases had become the major source of income for the Connecticut River Company by the mid-1840s.

The next canal built for steamboats came almost two years later on the Ohio River at Louisville. The Louisville and Portland Canal around the Falls of the Ohio was completed in 1831, but the first federal dam on the river, the beginning of the dam and lock system that made the Ohio a canalized river, was not begun until 1878 (Shaw 1990: 40, 126). By then, several states in the Ohio valley had gained considerable experience with canalized rivers for steamboat traffic (and for flatboats and keelboats as well).

The state of Ohio completed the Muskingum Improvement in 1841, a system of eleven dams and twelve locks that opened ninety miles of the Muskingum River to steamboat traffic from its mouth at Marietta to Dresden. In the same year, Kentucky opened a system of slackwater navigation on the Green and Barren rivers. Five locks canalized the rivers for two hundred miles, and allowed small steamboats to pass from one slackwater pool to another. Kentucky also canalized the lower Kentucky river between 1835 and 1845 (Whitford 1906, II:1428-1432, 1474-1475; Raber, Malone, and Parrott, 1991).

The Enfield Canal at Windsor Locks was thus a pioneering but ultimately unsuccessful step in river navigation improvement. The age of river steamboating was still in its infancy, but it was clear to the Connecticut River Company that steamboats had great potential. They did, indeed, on the lower, tidal Connecticut River, but it would have taken massive investments to make the upper river navigable for sizeable vessels. As it was, railroads soon eliminated most of the need for river traffic above Hartford. It was on America's canalized midwestern rivers that the concept of dams, locks, and by-pass canals for steamboat navigation found its most successful expression.

In waterpower development and hydraulic science, New England led the rest of the nation during the nineteenth century. The Connecticut River was justifiably famous for its waterpower and advanced turbine technology. Looking at federal census statistics, the waterpower developments in the Connecticut River basin were similar in scale to those in the Merrimack basin. Still, the former had more installed water power by 1880 (118,000 H.P. versus less than 80,000 H.P. for the Merrimack). The great Merrimack River textile communities of Lowell, Lawrence, and Manchester may have developed more quickly than the Connecticut's papermaking and turbine-testing center at Holyoke, but they fell short of its water power potential. The Connecticut was simply a more powerful river; Holyoke could claim a greater drop and twice as large a drainage basin as Lowell (Hunter 1979: 225-229). Had the dam, canal, and power plants at Windsor Locks ever been rebuilt to handle the potential of the Connecticut River at the Enfield Rapids, Windsor Locks would also have surpassed Lowell in water power. That fact falls into the "might have been" category. Although transportation priorities quickly gave way to power generation at the Windsor Locks Canal, the man-made channel never carried more than a fraction of the average flow in the Connecticut River.

The Connecticut River is beautiful and powerful. Even if it has never fulfilled its potential as a transportation artery or source of cheap energy, there is no reason for shame. The river's illustrious history is filled with stirring events and striking developments in power, transportation, and industrial technology. The river's greatest achievement, however, may be in its resistance to change. There is something ancient and vastly appealing in the way it looks, the way it moves, through both natural and man-made landscapes. Like the Mississippi, "it just keeps rolling along."

X. SOURCES AND RESOURCES

A. Overview

Preparation of this report involved review of the following types of material or information:

documentary sources, including unpublished primary manuscript material, published primary material such as corporate catalogues and annual reports, historic newspapers, and published and unpublished secondary works, found in a number of public and private libraries or archival collections;

portable industrial artifacts available at the Noden-Reed Museum and the M Corporation (formerly the Montgomery Company) in Windsor Locks, and the Smithsonian Institution in Washington, D.C.;

visually-inspected, extant structures and non-portable artifacts, including the Windsor Locks Canal and its engineering features, bridges or bridge sites over the canal and the river, and buildings and equipment owned along the canal by the Dexter Corporation and the M Corporation;

historic photographs, maps, views, and postcards available in some published works, and in the collections of the Noden-Reed Museum, the Connecticut Historical Society, the Museum of American Textile History in North Andover, MA, Howard White in Windsor Locks, and Lester Smith in Suffield;

paintings or other interpretative graphic material;

interviews or conversations with a wide variety of knowledgeable people.

We do not claim to have made an absolutely exhaustive search of all sources on all topics covered in this report. For example, there are considerable data in historic newspapers which could not be reviewed at this time. We believe, however, that we have identified virtually all types of documentary and material resources which might bear on future interpretation associated with the proposed River Canal Center and associated activities within the Heritage State Park. Additional research would be required to prepare some possible interpretative programs.

For future park planning, the most important fact about available sources and resources is that portable artifacts and historic visual materials are not very abundant. The documentary sources, while voluminous and in some cases incompletely tapped, rarely offer material amenable to display or interpretation. This means that any public interpretation will need to rely primarily on selective use of the natural and built environment, and on newly-created exhibits, programs, displays, and landscape management. We discuss each type of source or resource below.

1. Documentary Sources

An annotated bibliography of all documentary sources consulted for this report, including historic maps, appears below, (section X.B), with a key indicating those sources most useful on selected topics.

Other sources not yet used, in addition to complete runs of historic newspapers, include corporate archival material such as holdings of the Dexter Corporation used to prepare a recent manuscript company history (Anonymous c1988).

2. Portable Industrial Artifacts

Smithsonian Institution collections include one chuck made by E. Horton & Son Company; the Hagley Museum, Greenville, DE, has one other which we have not seen. The U.S. Naval Academy Museum, Annapolis, MD, has uniforms with braid containing components likely made by the J.R. Montgomery Company; images of similar uniforms are available at the Anne S.K. Brown Military Collection, Brown University. In Windsor Locks, the M Corporation has samples of tinsel and wire products associated with the Montgomery Company. The Dexter Corporation's Nonwovens Division has samples of its current products. The Noden-Reed Museum's small holdings comprise the largest known collection of pertinent, though largely undated, artifacts:

> *Dexter Corporation and its antecedents*: 1 packet, Dexstar Specialty Papers Lens Tissue; 1 catalogue (damaged) of Princess covers samples; 3 types of tissue wrapping paper made for F.W. Woolworth & Co.; 2 framed Princess covers; 1 small wooden spindle possibly used to wind paper; 1 1000-sheet packet, Star Mills Watercloset Paper:
>
> *J.R. Montgomery Company*: 1 sample card with cords used for electric shavers, telephones, and audio speakers; 1 ball of mercerized floss; 2 reels of silver and gold braid
>
> *E. Horton & Son Company*: 1 stationary envelope including a drawing of drill chuck Style B, patented March 21, 1893; 1 miniature cast cannon (painted black), produced for Philip Bailey's birthday
>
> *Medlicott Company*: 1 military wool undershirt; 1 red wool jacket
>
> *George P. Clark Company*: 1 stationary letterhead picturing examples of many trucks
>
> *William Muir & Company*: 1 U.S. Army contract percussion rifle-musket, Model 1861 or 1863, produced in 1864 as part of a 30,000-rifle contract, probably at the Denslow & Chase machine shop (see Site 6, Table 1; Flayderman 1983: 452)
>
> *John Chase, Denslow & Chase Machine Shop*: 1 original patent model of an appliance for carbureting air, patented November 14, 1865 (see Site 6, Table 1)
>
> *F.S. Bidwell*: 1 1904 catalog (partly burned)

3. Structures and Non-Portable Artifacts

The Windsor Locks Canal survives in generally excellent condition, as the best-preserved canal in New England. The aqueduct, although modified repeatedly, is the only intact structure of its type in the region. Most current canal conditions are summarized in a recent engineering study (Maguire Group Inc. 1988). Other features, in varied states of preservation, include the three lift locks at the canal's lower end and their basins, the Suckerhouse and associated outbuildings immediately above the upper lift lock, and fragmentary remains of a stone block stopgate pier on the west side of the canal about 4300 feet south of the headgates (Figure 2).

At present, there are some remains of all historic bridge crossings except the Windsor Locks-Warehouse Point suspension bridge, removed for the new bridge now being completed, and the Thompsonville bridge. As noted above (section III.D.3), some cable fragments and iron saddles survive from the suspension bridge under informal arrangements, and may be available for display (personal communication, David A. Poirier). The Enfield Bridge pier bases survive as vegetation-sprouting islands in the river. The railroad bridge includes masonry components of all four structures erected at this crossing. The 1921 steel truss bridge is currently in use, but will be demolished in the relatively near future.

The Dexter, Montgomery, and Horton complexes survive, and include buildings from many construction episodes after 1865. The 1865 Horton building is the oldest industrial structure on the canal. The Horton and Montgomery complexes have been described for National Register of Historic Places listing (Ransom 1989). Textile-twisting and wire-drawing machines survive in the former Montgomery complex, most of them now inoperable; similar machines can be seen in Littleton, NH making Montgomery-style wire for a German-American (Waidhaus and National Wire & Cable) consortium which bought most Montgomery manufacturing interests (personal communications, Spencer Montgomery and Robert Brengi). The operating Dexter complex, with structures and equipment dating to c1875, remains to be described.

The c1875 station of the New York, New Haven, and Hartford Railroad survives in good condition. This brick structure with Italianate and Queen Anne elements is listed on the National Register of Historic Places (Ransom 1989). Other important railroad resources in Windsor Locks include several ashlar brownstone culverts, one of which has a brick-lined arch.

The Town of Windsor Locks includes many residential buildings, and a few institutional structures such as Memorial Hall, reflecting the impact of the canal on the local community. These resources remain to be described.

4. Historic Graphic Resources

The bibliography below includes all maps and birdseye views used for this report, and indicates those with particular visual or historical values. Published works with historic views are also indicated.

The Noden-Reed Museum has photographic and drawn portraits of many Windsor Locks industrialists and their families, and a small number of photographs and postcards showing the suspension bridge, the Dexter

and Montgomery factories at various times, the Dexter gristmill, Main Street in Windsor Locks, the 1936 flood, and group portraits of local workers or formal immigrant associations. Nearly complete original runs of the Windsor Locks Journal, at this museum, include large numbers of views which we did not inspect.

The M Corporation and the Museum of American Textile History have line drawings of plants of the J.R. Montgomery Company c1875-92, and of the H.C. Dwight & Co. plant c1880, prepared by Barlow's Insurance Survey. M Corporation also has portraits of several Montgomery family industrialists.

Lester Smith's personal collections include postcards and photographs of several historic bridges in the rapids area. Howard White's personal collections include a large number of photographs taken of the Dexter plant in the 1950s and 1960s, and several 19th- or earlier 20th-century photographs of railroad activity and bridges in Windsor Locks. There are several large, composite panoramic photographs of Windsor Locks along Main Street or the river in the Windsor Locks Town Hall, along with a poster announcing the "public jollification" held in 1909 to celebrate the removal of tolls from the suspension bridge.

The Connecticut Historical Society's collections include what is probably the original of a frequently-reproduced lithograph of the Persse & Brooks plant c1857 (in Colton 1857), along with several other photograph and contemporary historical sketches (see Connecticut Historical Society 1981). The Kent Memorial Library in Suffield has an untitled c1830-35 profile comparing the New Haven to Northampton Canal to Connecticut River navigation below Northampton (Folder H - Railroads - Street).

5. Other Graphic Interpretations

Andrew N. Wyeth, Willimantic, CT, has painted several recent watercolors of the canal aqueduct which capture the canal's place in the river environment.

The Noden-Reed Museum and the Warehouse Point Public Library have undated sketches and watercolors of local scenes, including the Windsor Locks-Warehouse Point ferry and the Terry family wire-guided boat at King's Island.

Some published sources, indicated in the bibliography, have reproductions of
drawings or paintings of the canal, river craft, or general river scenes.

6. Personal Communications and Interviews

Persons consulted are listed below (section X.C). This is not an exhaustive list of people with valuable information on park area history.

B. Bibliography

Hard-to-locate sources include current locations, in brackets. The most useful sources on various topics for possible future interpretation are indicated as follows:

(R): descriptions of the river and natural environment
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